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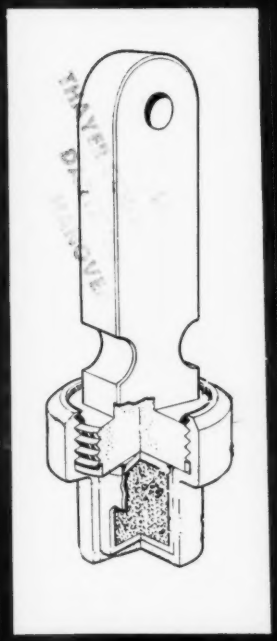

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Russian reactors

The Physical Society show

February 1961
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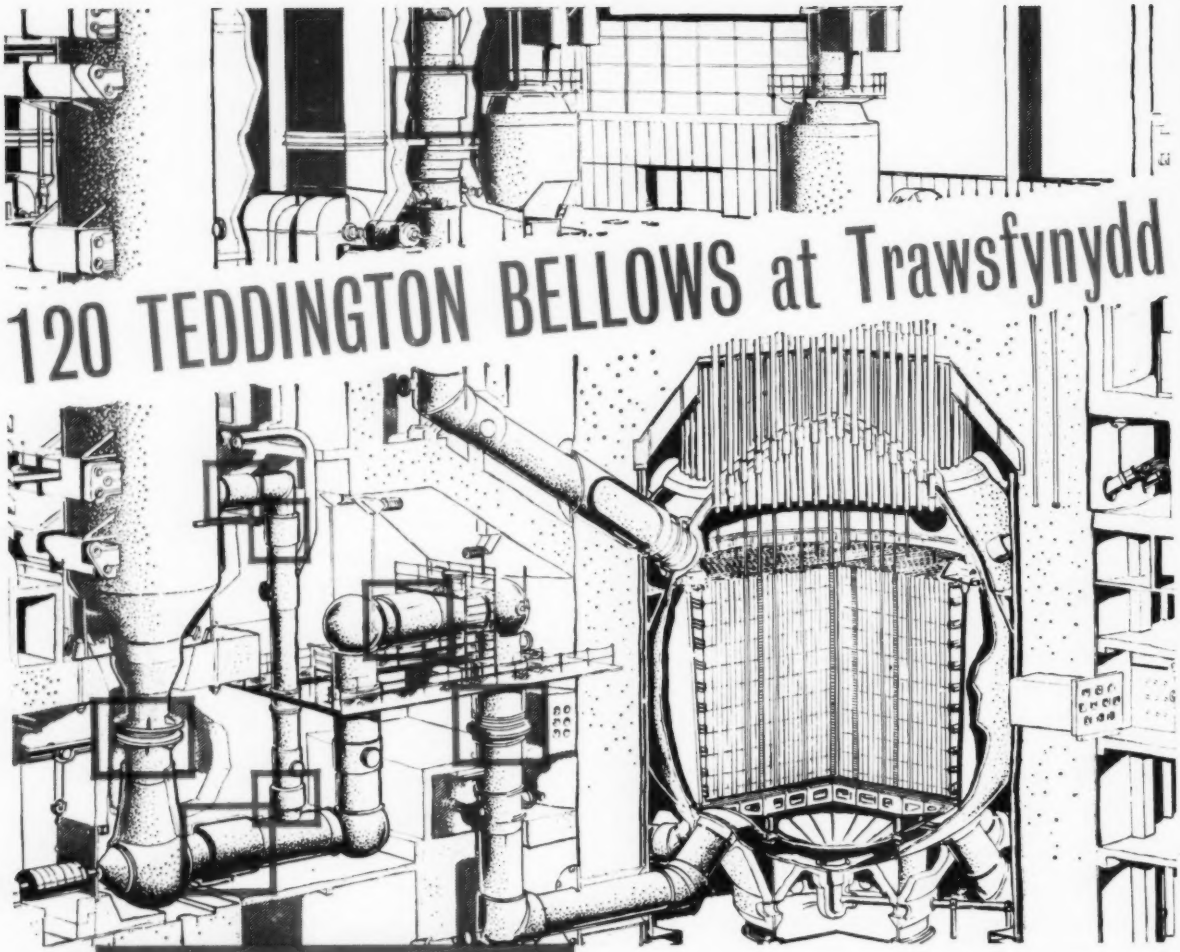
120 TEDDINGTON BELLOWS at Trawsfynydd



By courtesy of 'NUCLEAR POWER'

Illustration A represents one of the Teddington Stainless Steel Bellows supplied to Trawsfynydd with a novel form of restraint designed by Richardsons, Westgarth & Co. Ltd. of the A.P.C. Group. This avoids the use of highly stressed hinge pins and permits a complete gimbal movement.

Illustration B indicates a section of Teddington Bellows showing the restraining rings for extra strength which are a feature of this bellows design.

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COVER PICTURE

This month's cover shows a caesium-137 probe being used for weld radiography, and a section of the source

Nuclear Power

REACTORS · MATERIALS · INSTRUMENTATION · PROCESSES · IRRADIATION

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LOOKING FOR A JOB? SEE PAGE 127 AND ONWARDS

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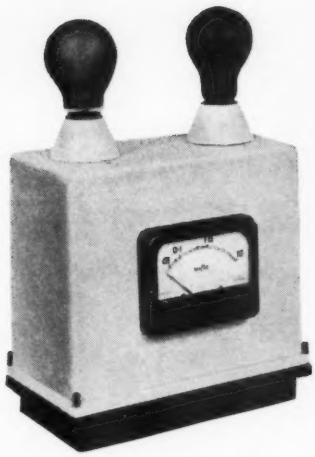

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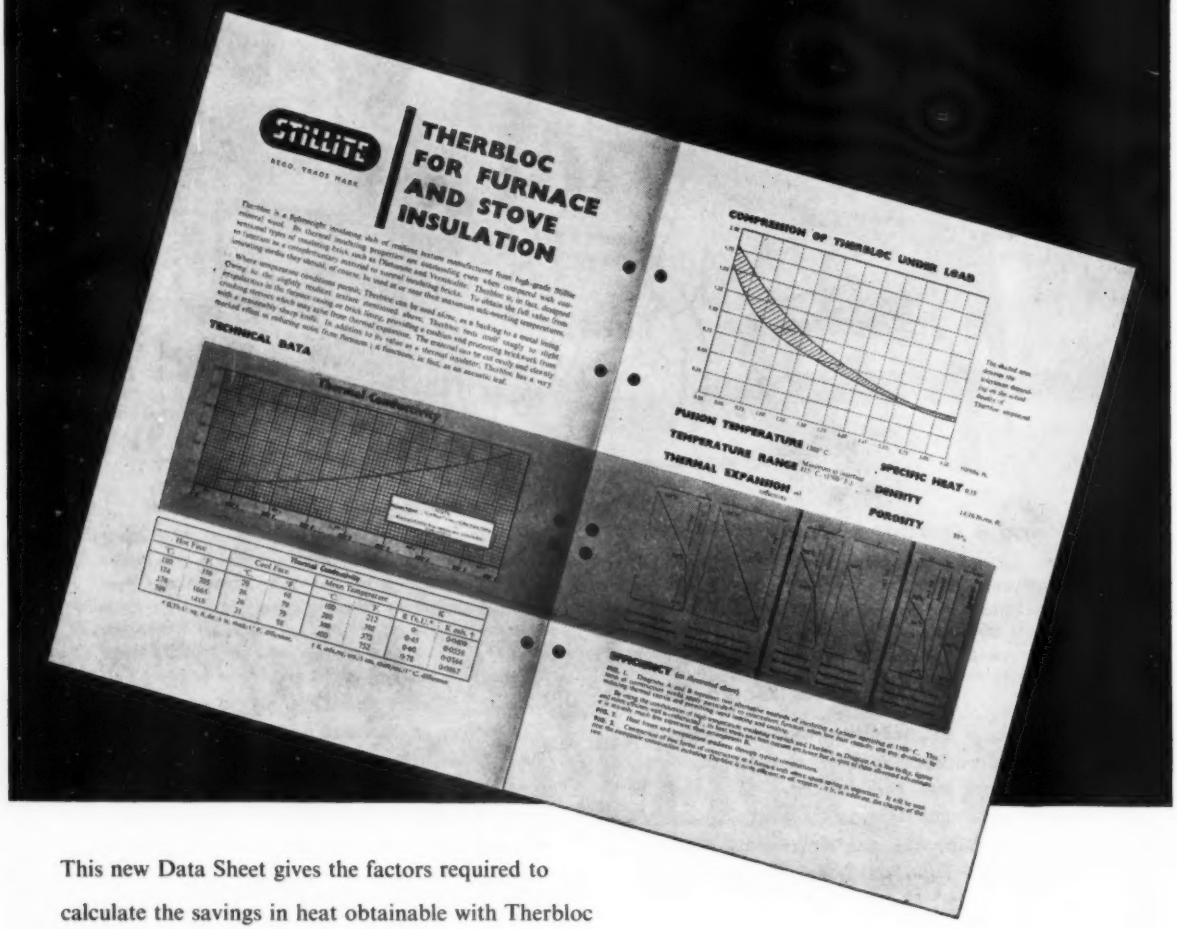

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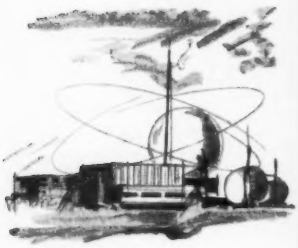

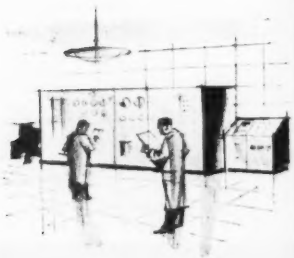

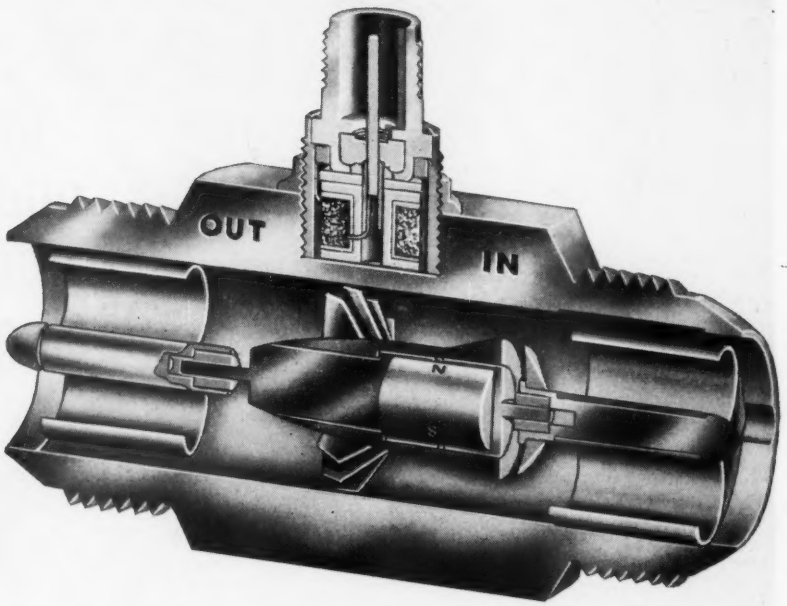

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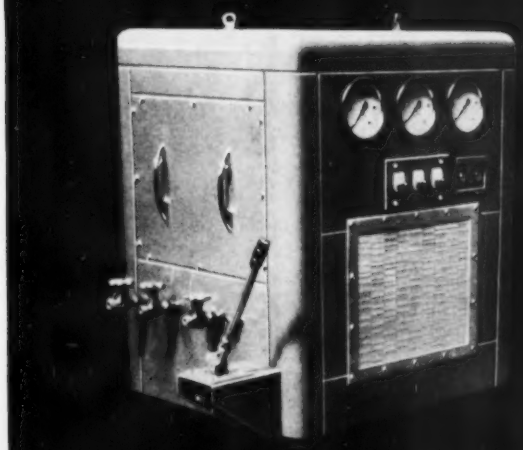

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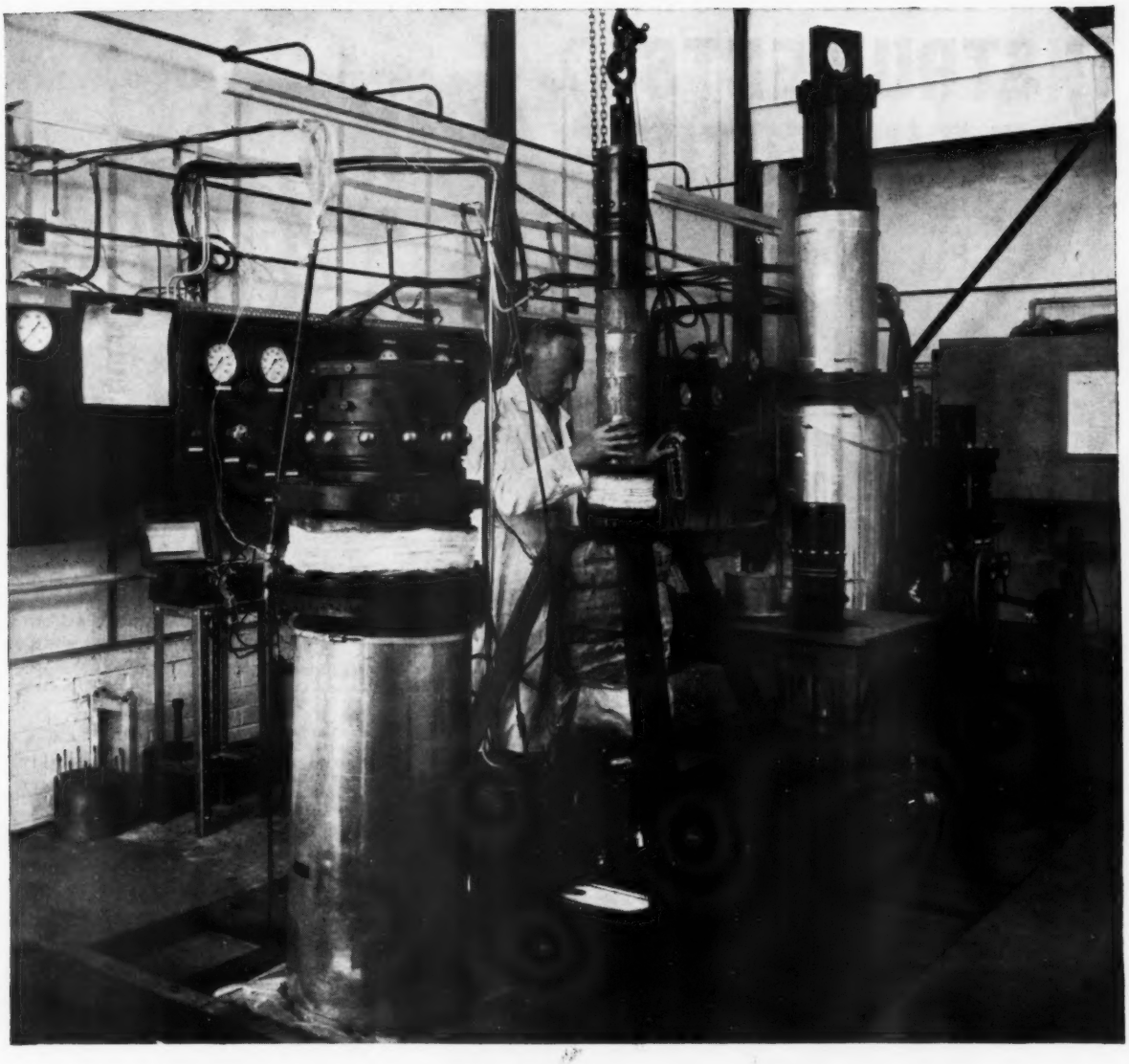

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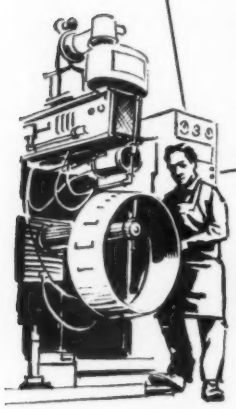

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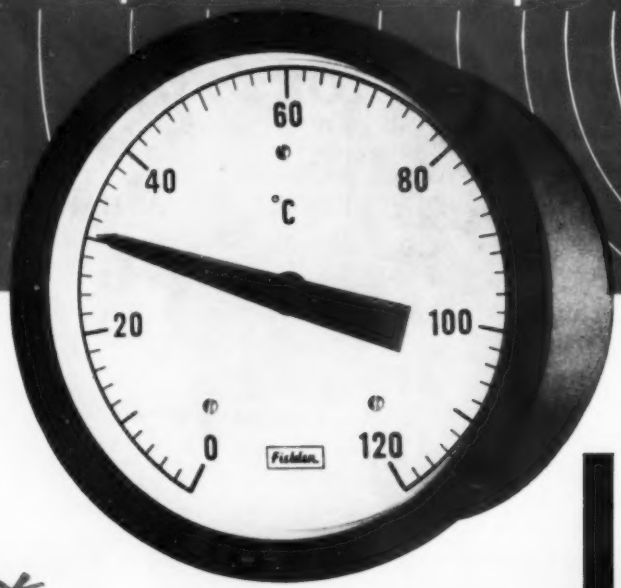

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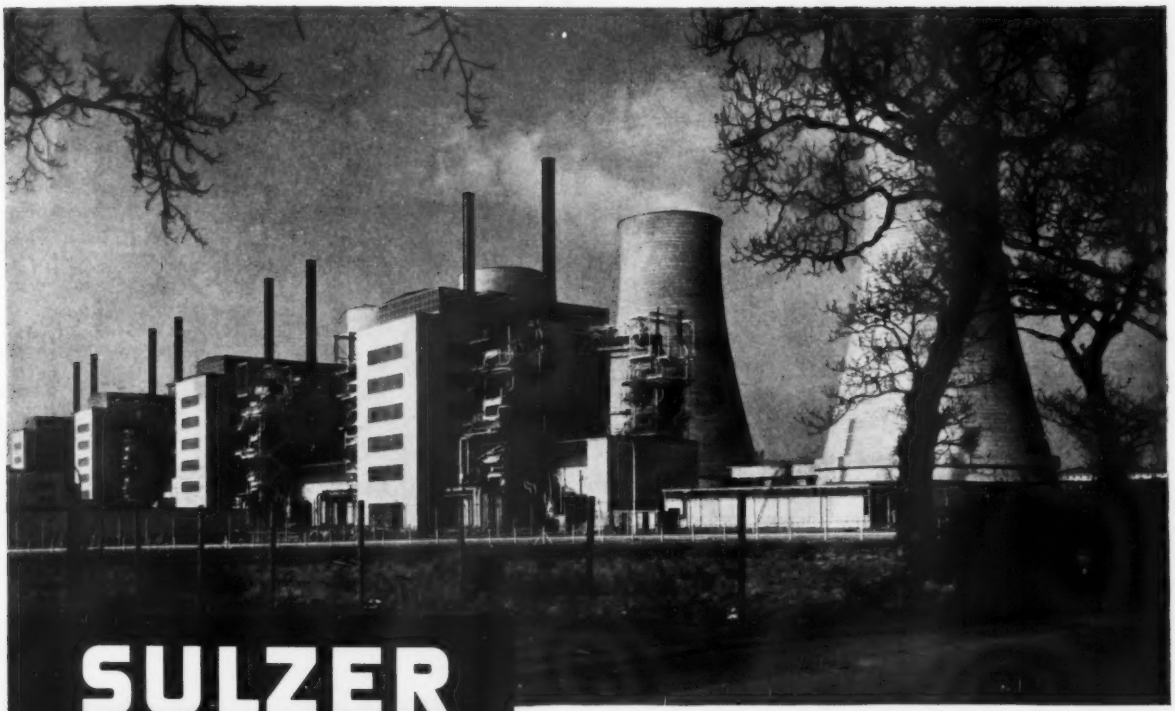

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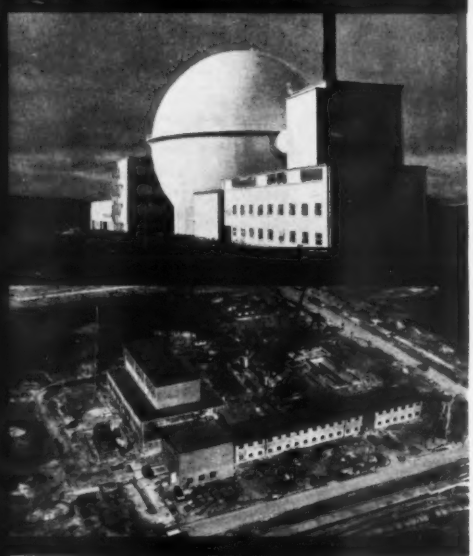

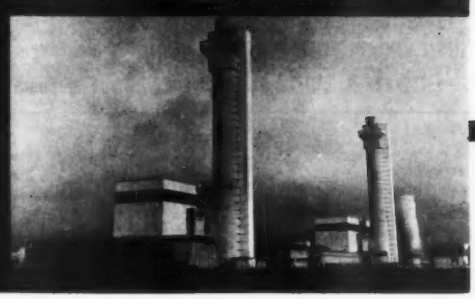

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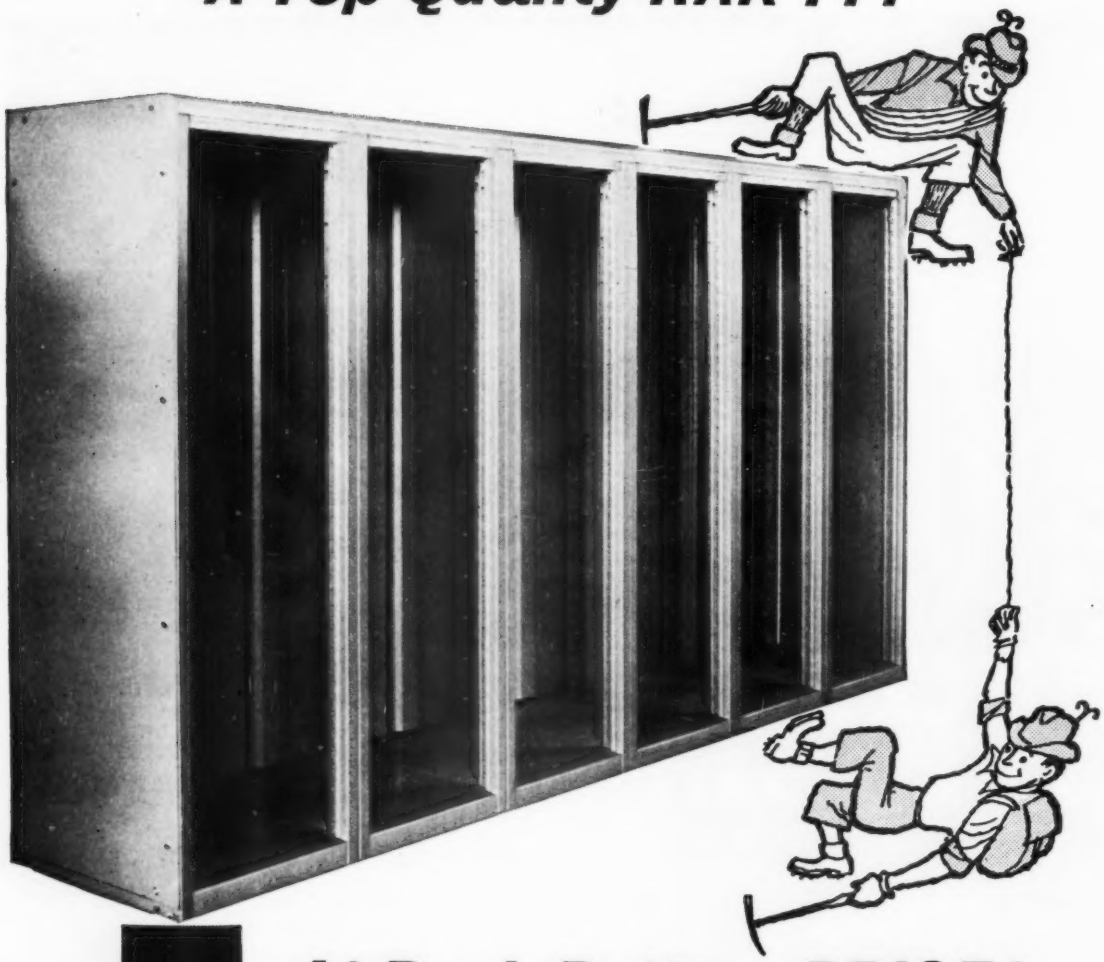

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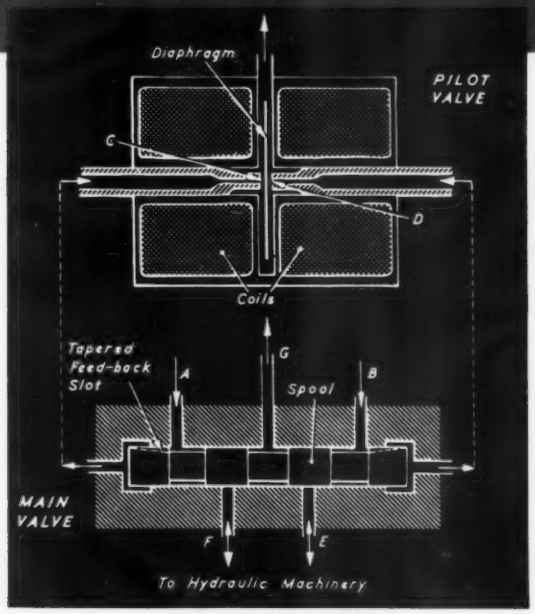

The valve — see diagram — consists of a main valve and a pilot valve. The main valve is supplied with pressure oil through ports A and B. When the spool is in the central position — as shown — the oil escapes through the tapered slots to the opposed jets C and D in the pilot valve and impinges on each side of the diaphragm. The two coils can be energised to attract the diaphragm towards one or other of the jets. If the signal to the right hand coil is the stronger, the diaphragm will flex to the right, restricting the flow from the right hand jet and thus increasing the pressure in that line. Similarly, the pressure in the left hand line is reduced. This pressure difference is transmitted to the main valve and causes the spool to move to the left until the resultant decrease in discharge area of the tapered slot at the right hand end of the spool and the increase in that at the left cause equilibrium to be restored. The displacement of the spool uncovers ports E and F, thus opening pressure and return lines to the hydraulic machinery.

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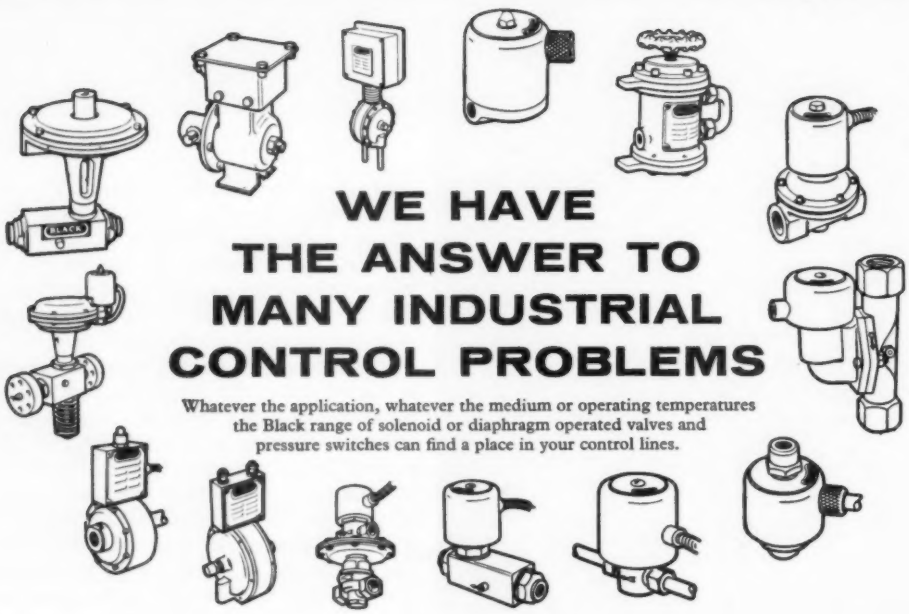

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of a millimetre in size has only

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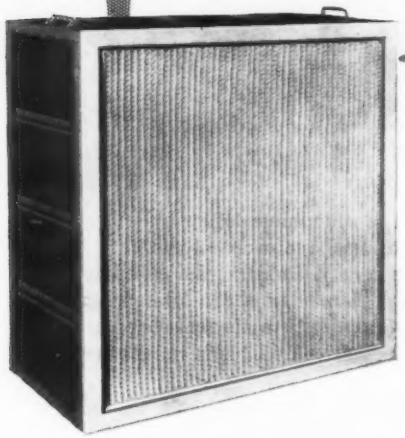

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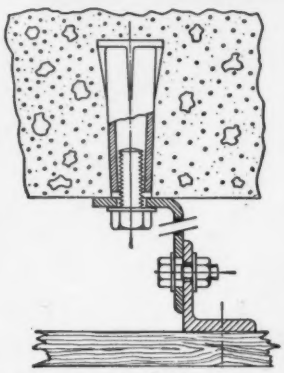

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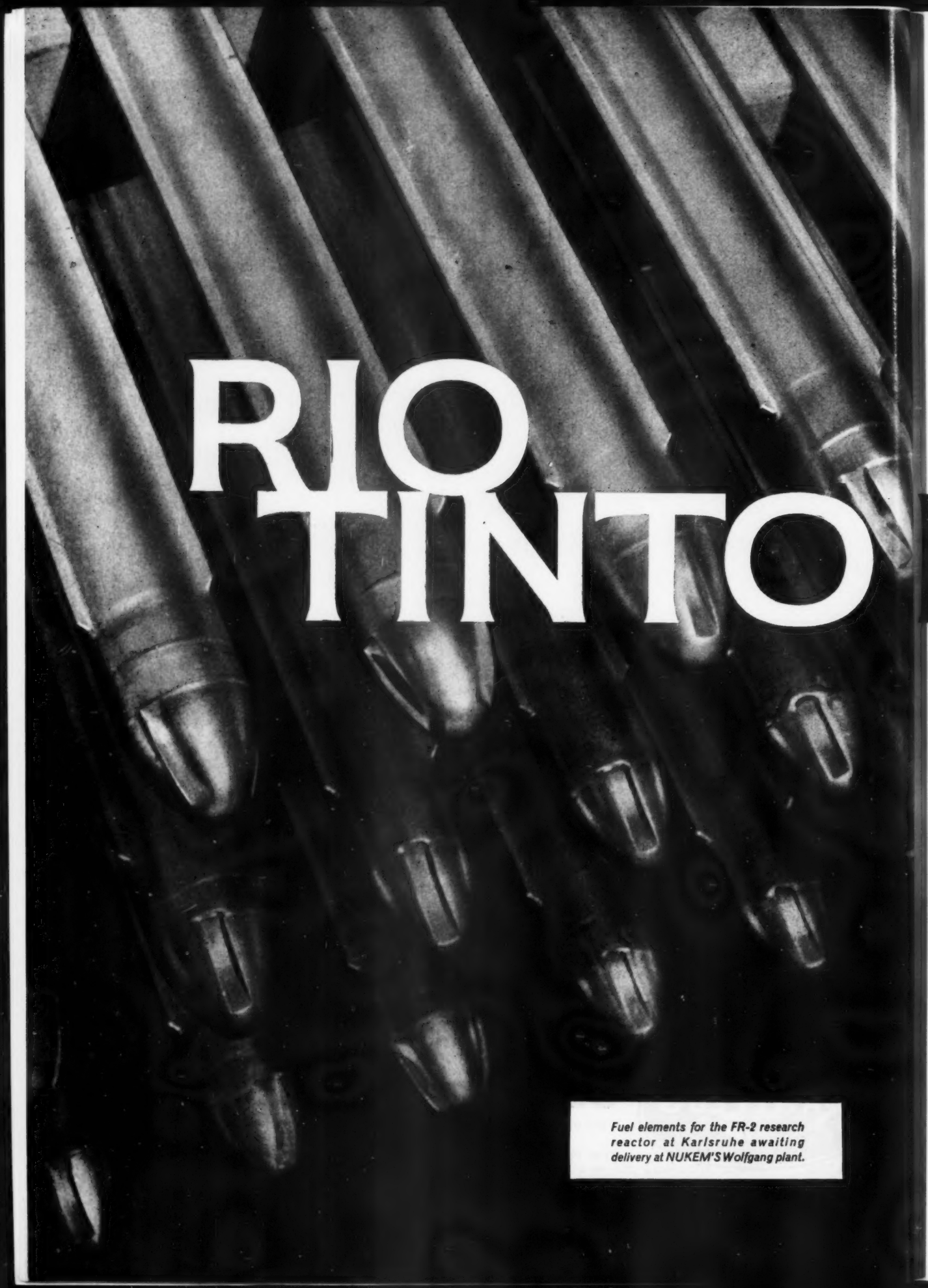
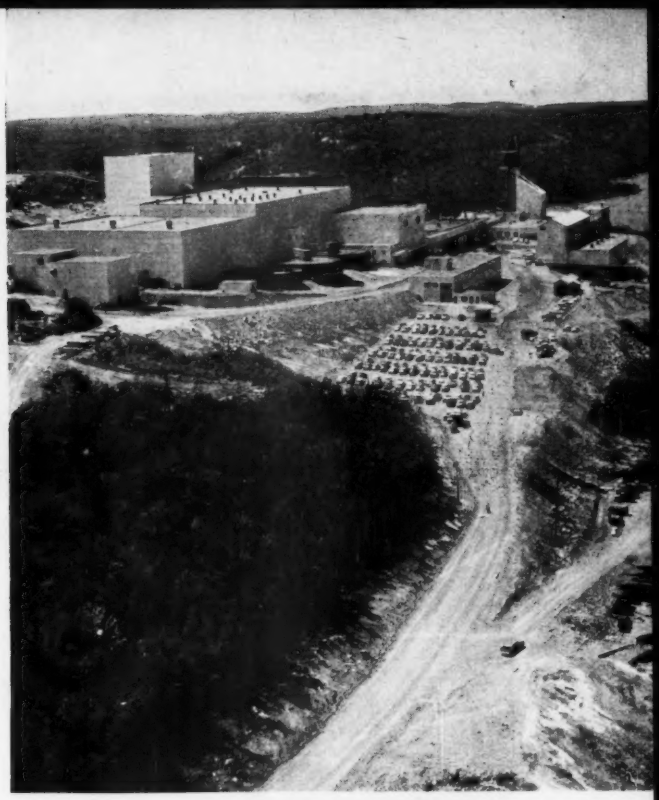


Fuel elements for the FR-2 research reactor at Karlsruhe awaiting delivery at NUKEM'S Wolfgang plant.



The 3,000 ton per day Nordic uranium concentrating plant of Rio Algom Mines Limited, Canada.

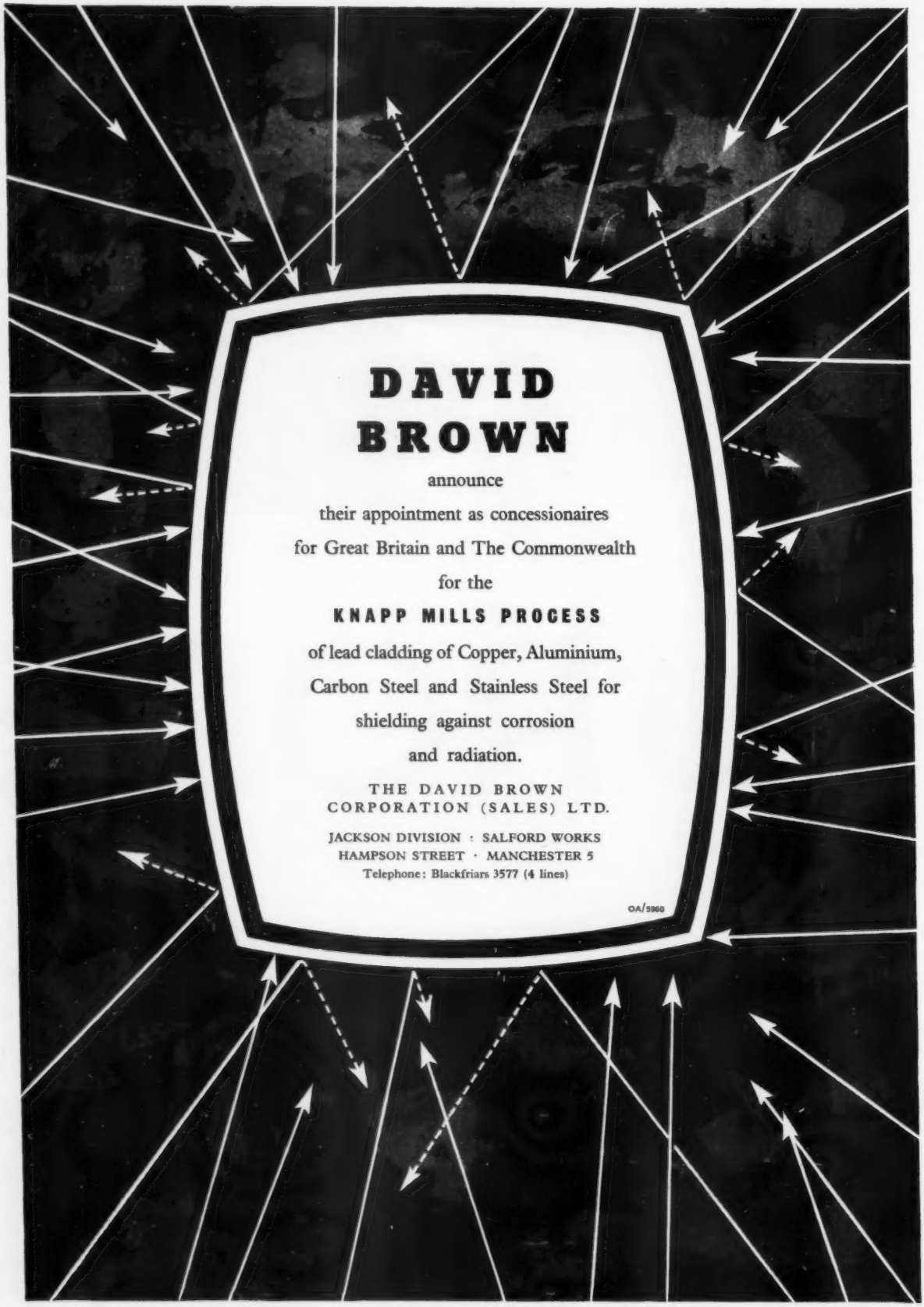
IN EUROPE

Rio Tinto has joined forces with the leading German metallurgical group, Deutsche Gold- und Silber-Scheideanstalt vormals Roessler (Degussa), to form NUKEM—Nuklear-Chemie und -Metallurgie Gesellschaft m.b.H.

NUKEM has taken over the research and production programme of the Degussa Nuklear Gruppe, covering a wide range of uranium and thorium processing and fabricating activities related to the nuclear power programmes of a number of countries.

NUKEM is co-operating closely with Rio Tinto's Canadian uranium mining interests and with Rio Tinto Dow Limited, a company specialising in uranium and thorium processing.

Nukem—Nuklear-Chemie und -Metallurgie Gesellschaft m.b.H., Wolfgang bei Hanau (Main)
Rio Tinto Management Services (U.K.) Limited, Barrington House, 59, Gresham Street, London, E.C.2.
Deutsche Gold- und Silber-Scheideanstalt vormals Roessler (Degussa), Weissfrauenstrasse 9, Frankfurt (Main)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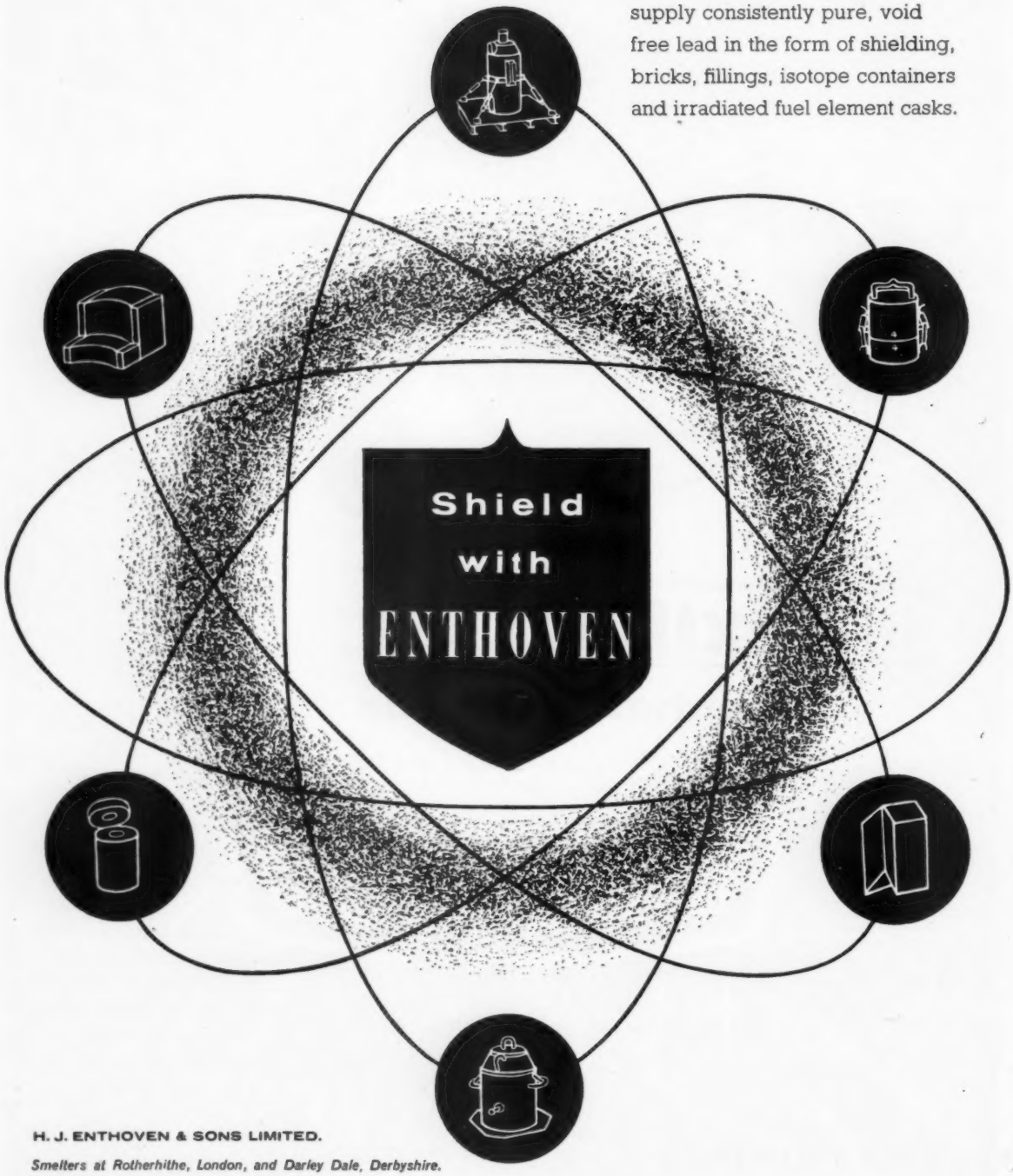

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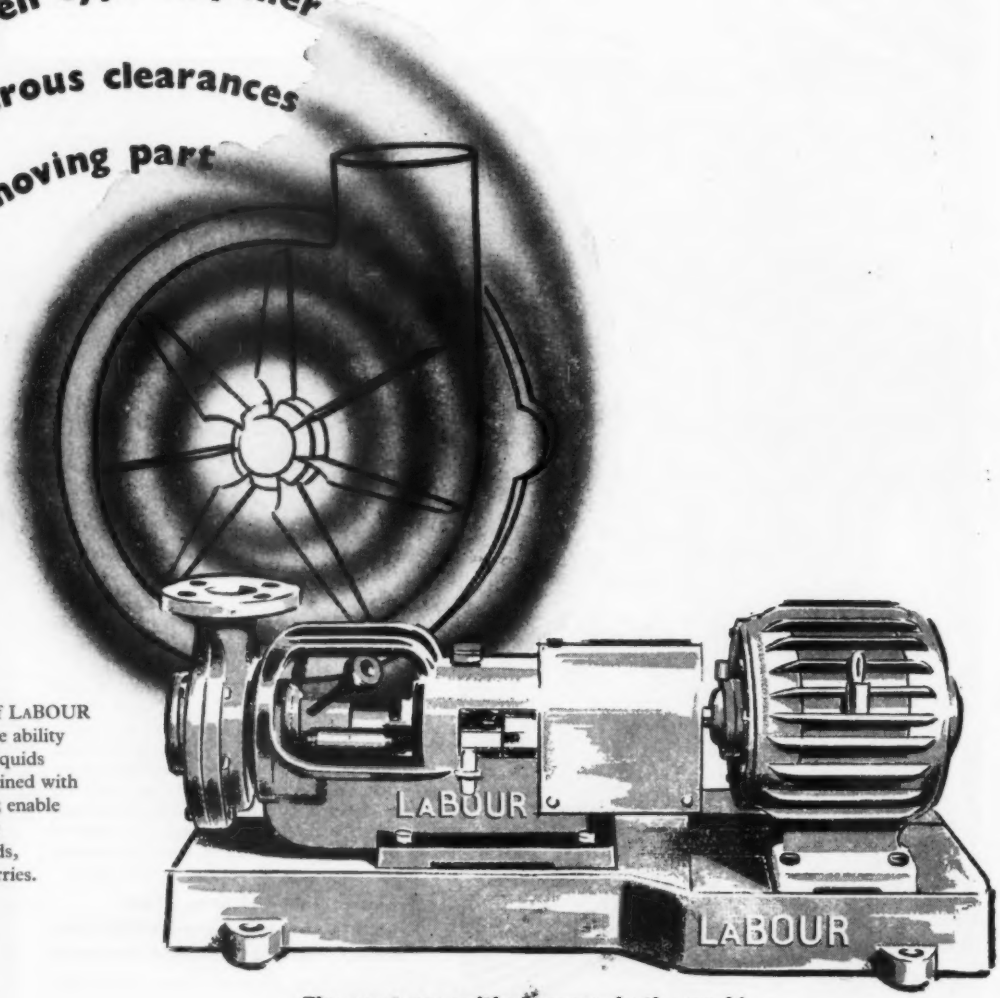

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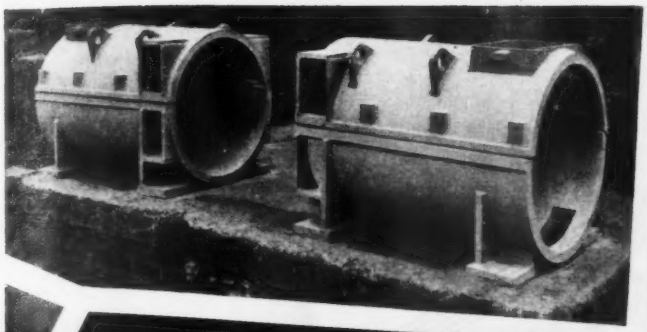

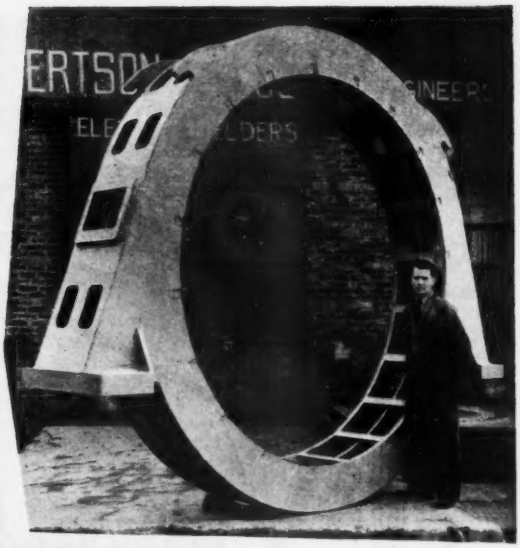

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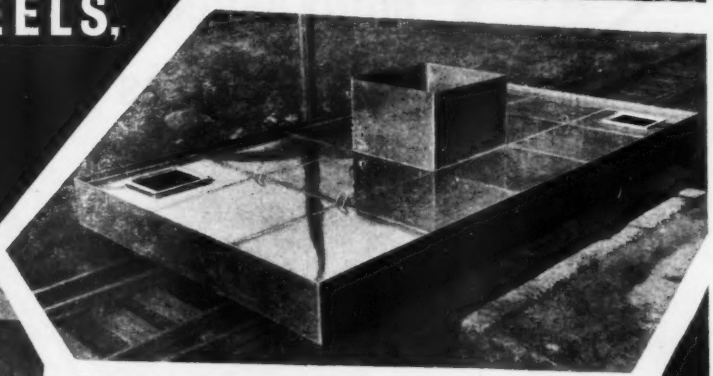

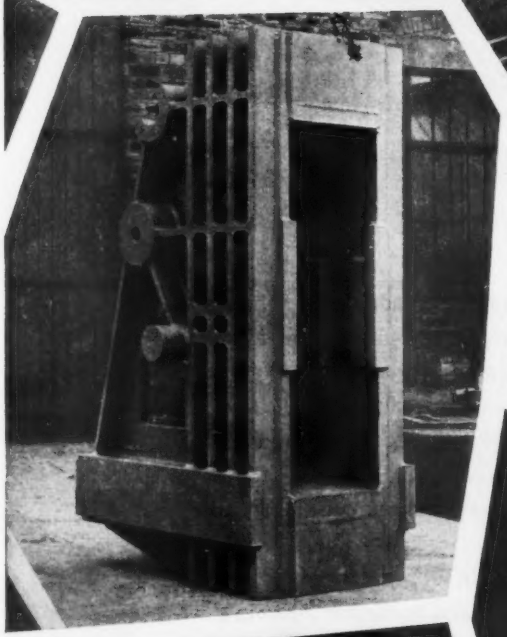

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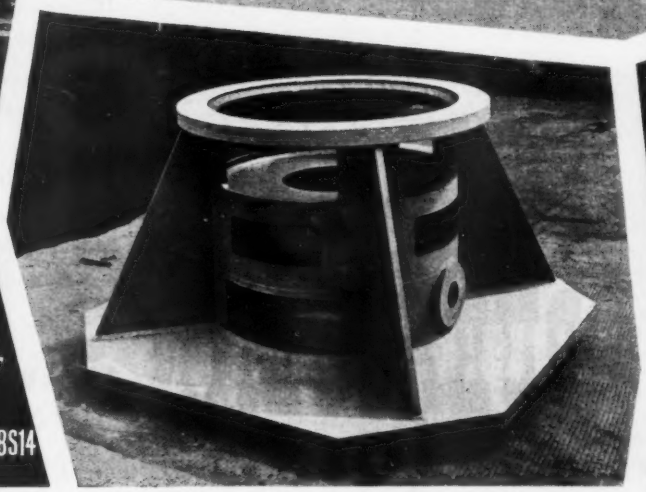

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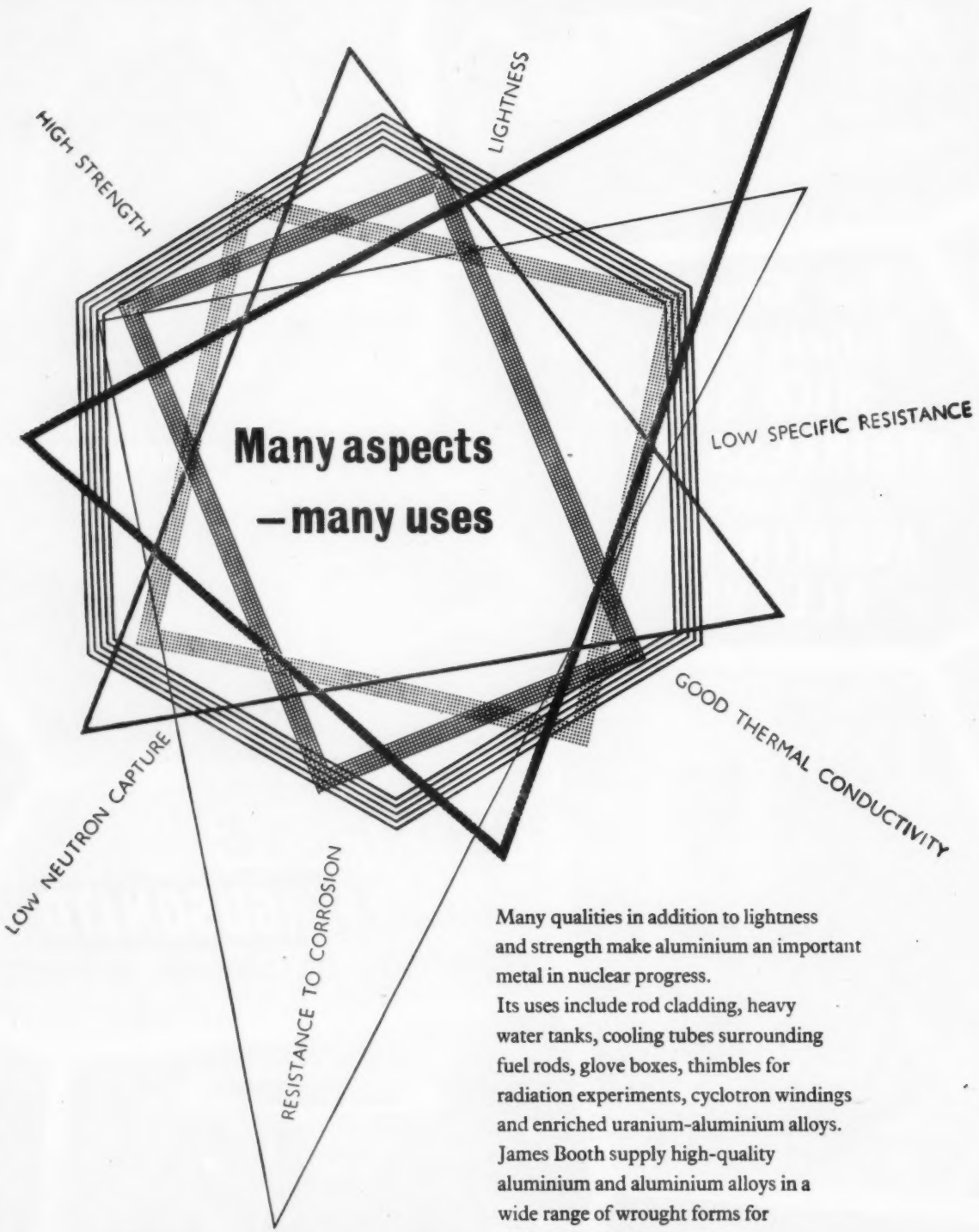

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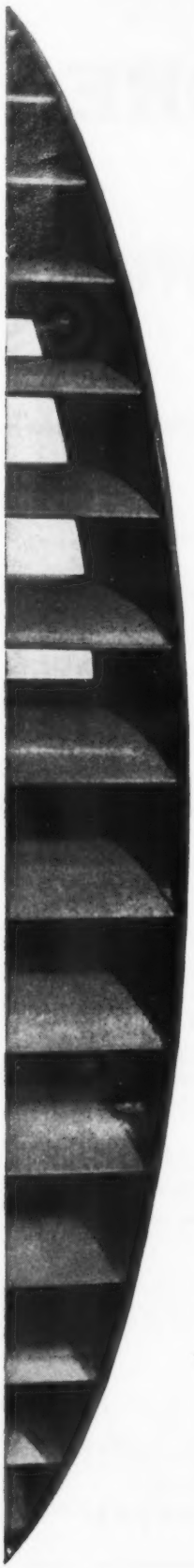
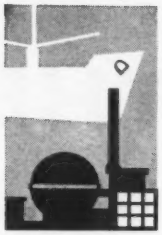
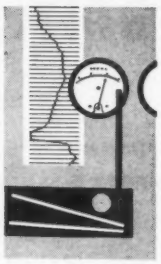


formula for leadership



Experience Founded originally in 1823 the Company has had the widest experience in the design and manufacture of all types of equipment for the handling of air and other gases. Blowers, exhausters, heaters, filters, dust and fume removal equipment, and of course, fans of all types, fall within this wide scope. Fans of every size and for every purpose, from Coal Mines to Aircraft Carriers, have been designed, manufactured and tested by Keith Blackman and installed in all parts of the world—experience unparalleled in the field.



Research Keith Blackman's lead in design is maintained by five separate research departments. Specialised facilities are available at Tottenham for the development and testing of axial fans, centrifugal fans and filtration equipment, while a metallurgical laboratory controls the quality of materials founded at Arbroath. Tottenham also possesses one of the most advanced acoustics laboratories in the world for the investigation of sound levels in all types of fan engineering equipment.
In addition, the company's generating station, as well as supplying power to the factory, is designed to produce a wide range of A.C. and D.C. supplies for the test beds.

Range The Keith Blackman range covers virtually every type of fan and blower in all sizes—axial types from 5 inch to 100 inch diameter, centrifugal types ranging from 1¼ inch to 180 inch, and propeller fans from 6 inch to 72 inch diameter. Much equipment is designed for clients' specific requirements involving, frequently, the use of special materials including pvc. Other equipment is made for heating, cooling, washing, dust and fume extraction, filtration and air conditioning. *Five thousand fans of varying types are kept continuously in stock for quick delivery.*

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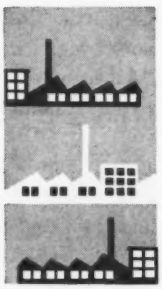
Leaders in the Fan Industry



Resources The company's three factories cover an area of 17½ acres, and employ over 1,800 people. The main Tottenham works produces small and medium units and includes drawing offices, test facilities and machine shops, as well as the sales and administration offices.
The Arbroath works deals with the production of the larger fans. Its iron and non-ferrous foundry plant supplies the whole of the company's casting needs.
The Edmonton Factory concentrates on light sheet metal and plate work and the fabrication of steel structures.
Virtually all components, including fan motors and bearing housings, are thus designed and manufactured within the organisation—a unique combination of resources.

Service Through the years the company has built up an enviable reputation for service at all stages. Sales representatives are all fully trained technical men capable of giving 'on the spot' advice on routine applications or special problems. The sales organisation operates from branches throughout the country backed by a staff of qualified sales engineers at Head Office.
Despatch of stock items, of which 5,000 units are kept continuously available, is possible in as little as four days. The Company has its own road transport fleet and direct rail connections from the main factory.

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OF ALL

BRITISH REACTORS

Low neutron capture cross section

High apparent density

Good strength

Ease of machining

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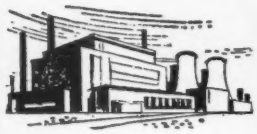
THERMAL INSULATION BY Newalls

Throughout the years Newalls have built an enviable reputation in the insulation of conventional power stations. This specialised experience is now being drawn upon on an ever growing scale in solving the complex problems of Nuclear Power Development. Recent contracts in this field reflecting Newalls supremacy are:—



HINKLEY POINT

C.E.G.B. NUCLEAR POWER STATION

At Hinkley Point, Newalls have been entrusted with the insulation of the reactors steam raising units, gas ducting, integra piping, etc. under contract to Babcock and Wilcox Ltd

CHAPELCROSS

U.K.A.E.A. NUCLEAR POWER STATION

Under contract to Babcock and Wilcox Ltd., Newalls have carried out the insulation of the 16 steam raising units and integral piping. The insulation of turbines, blowers, associated auxiliary equipment and piping has been carried out under contract to C. A. Parsons and Co. Ltd.

BRADWELL

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At Bradwell-on-Sea a further large contract for the thermal insulation of .urbines, associated auxiliary equipment and piping (main and auxiliary turbine plants) has also been placed by C. A. Parsons and Co. Ltd. with Newalls.

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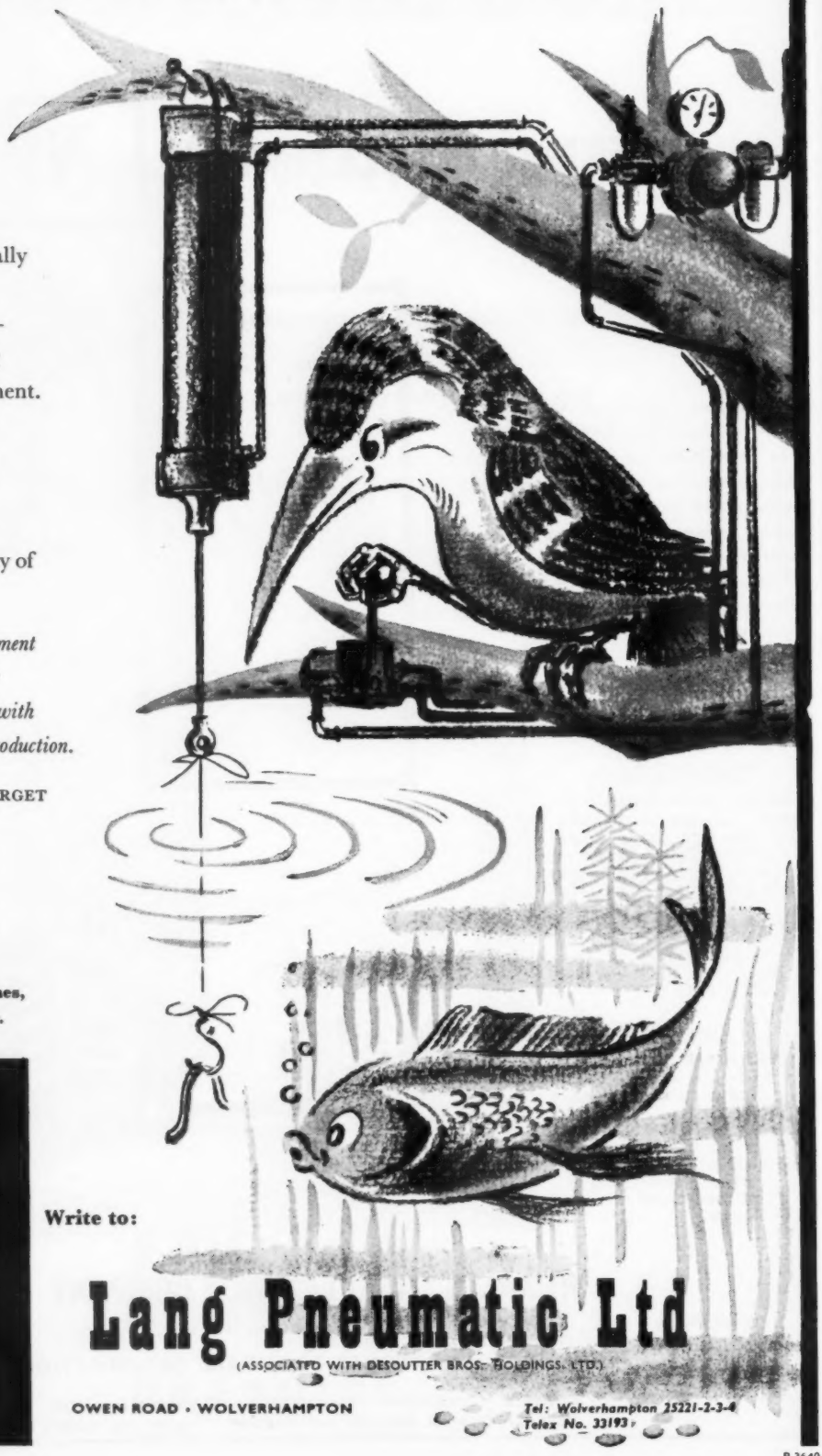

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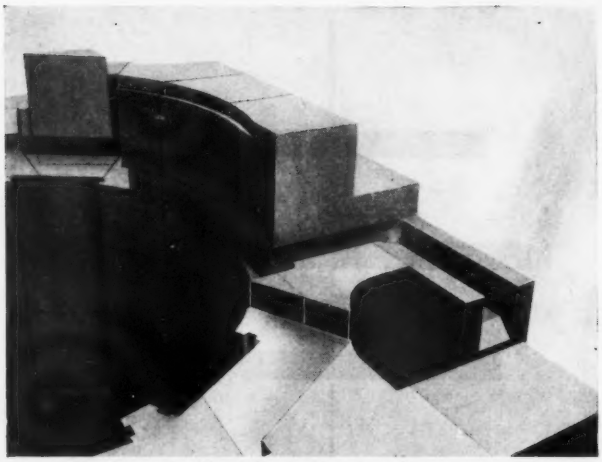

Sections of a "Jason" reactor recently completed for the Hawker Siddeley Nuclear Power Co. Ltd.

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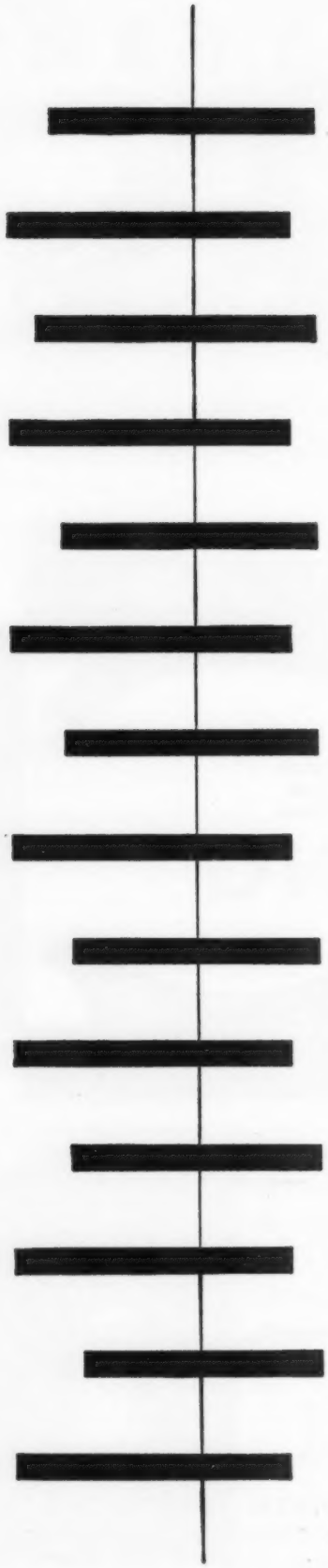

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53AVP Eleven stage tube with 44 mm diameter photocathode for use in gamma spectroscopy.

53UVP As 53AVP but with quartz end window to give sensitivity to ultra-violet.

54AVP Eleven stage tube with 111 mm diameter photocathode for flying spot scanners.

56AVP Fourteen stage tube with focused dynode structure giving rise time and transit time spreads of 2×10^{-9} s. 42 mm diameter photocathode.

56UVP As 56AVP but with quartz end window.

57AVP Eleven stage tube with large photocathode 200 mm in diameter.

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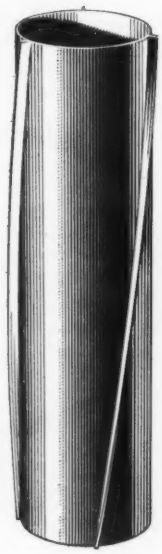

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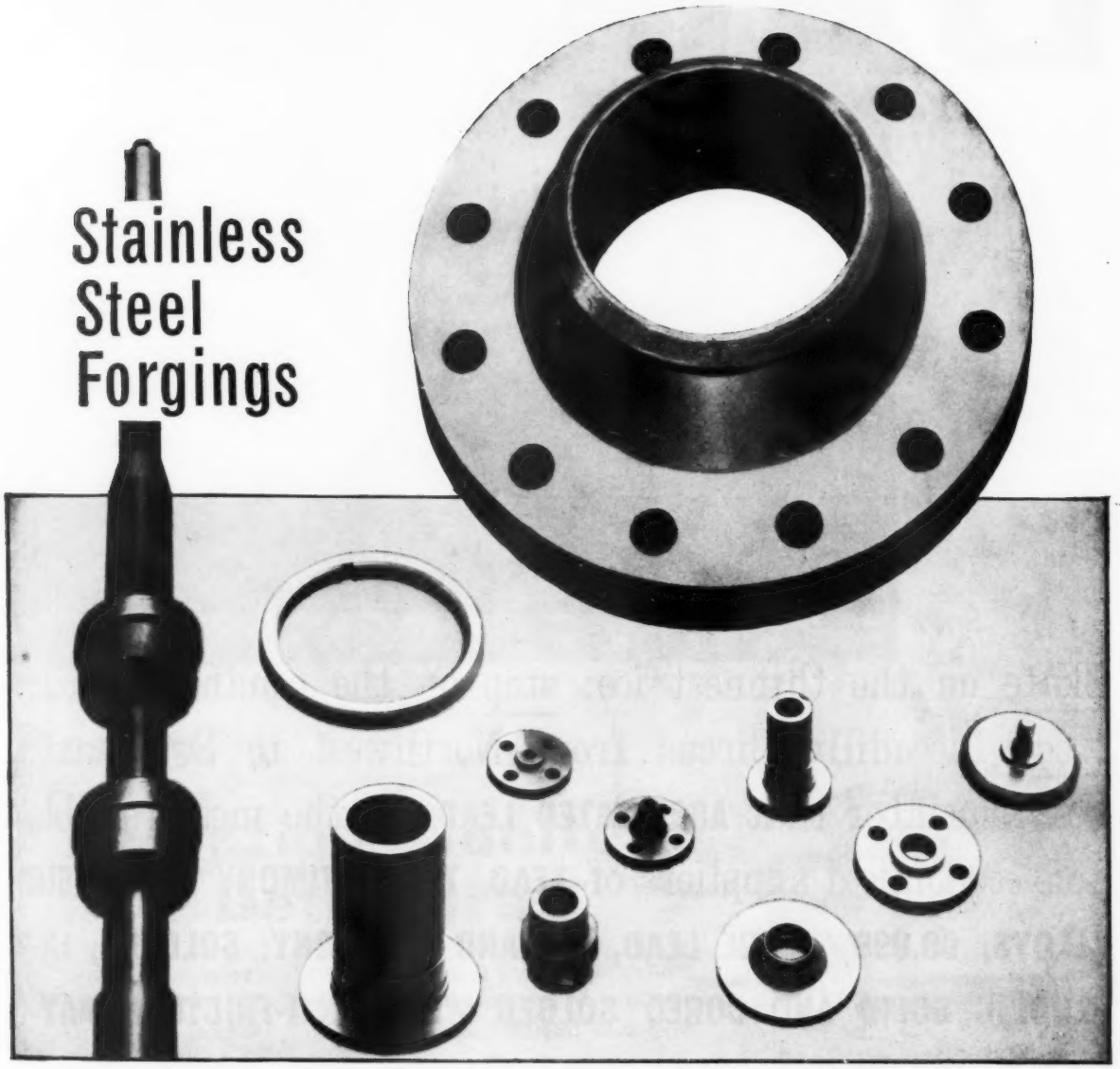

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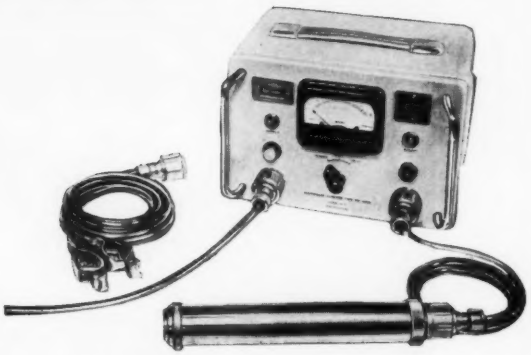

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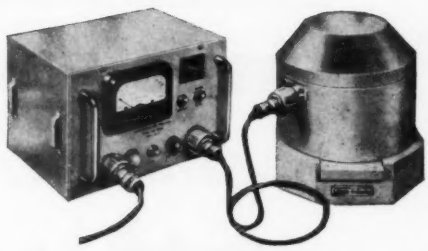

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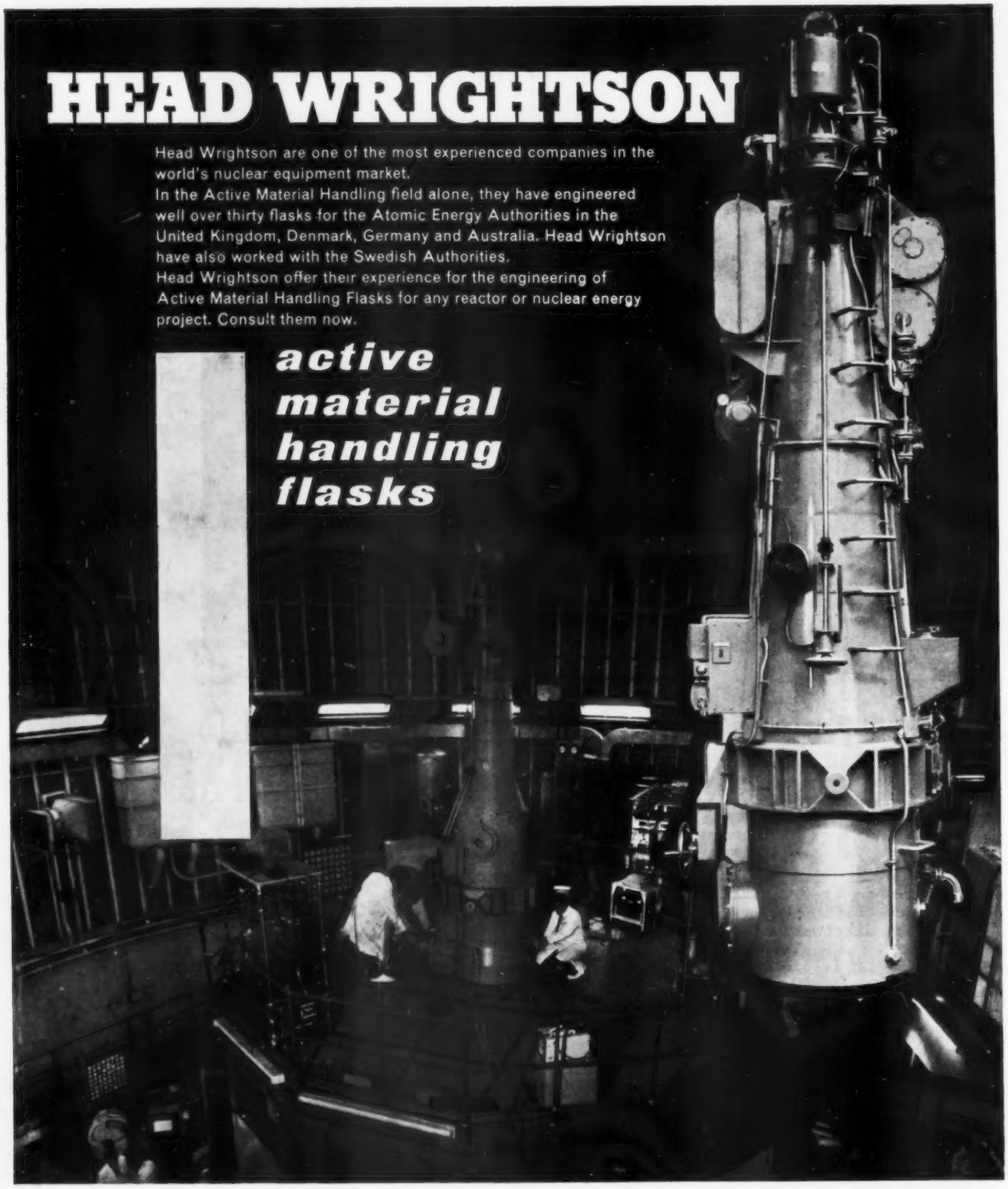

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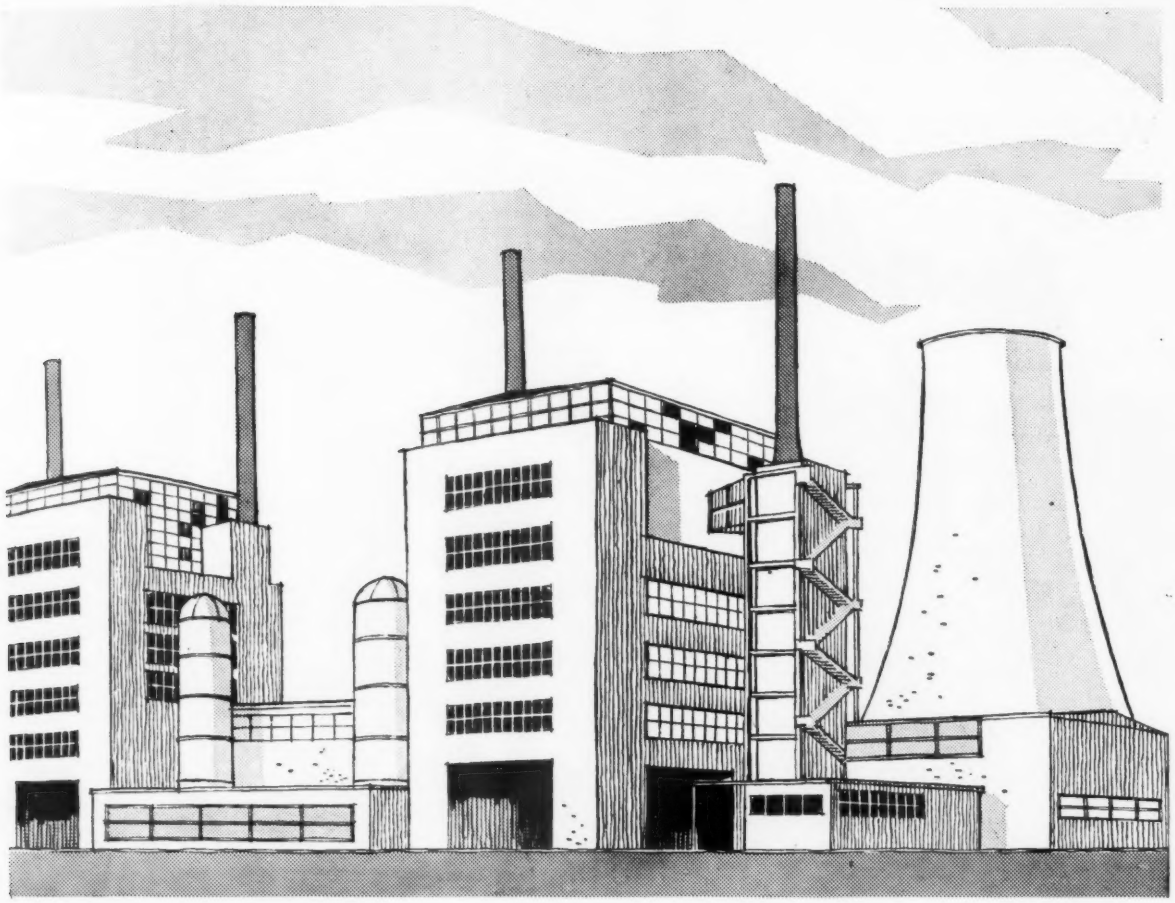

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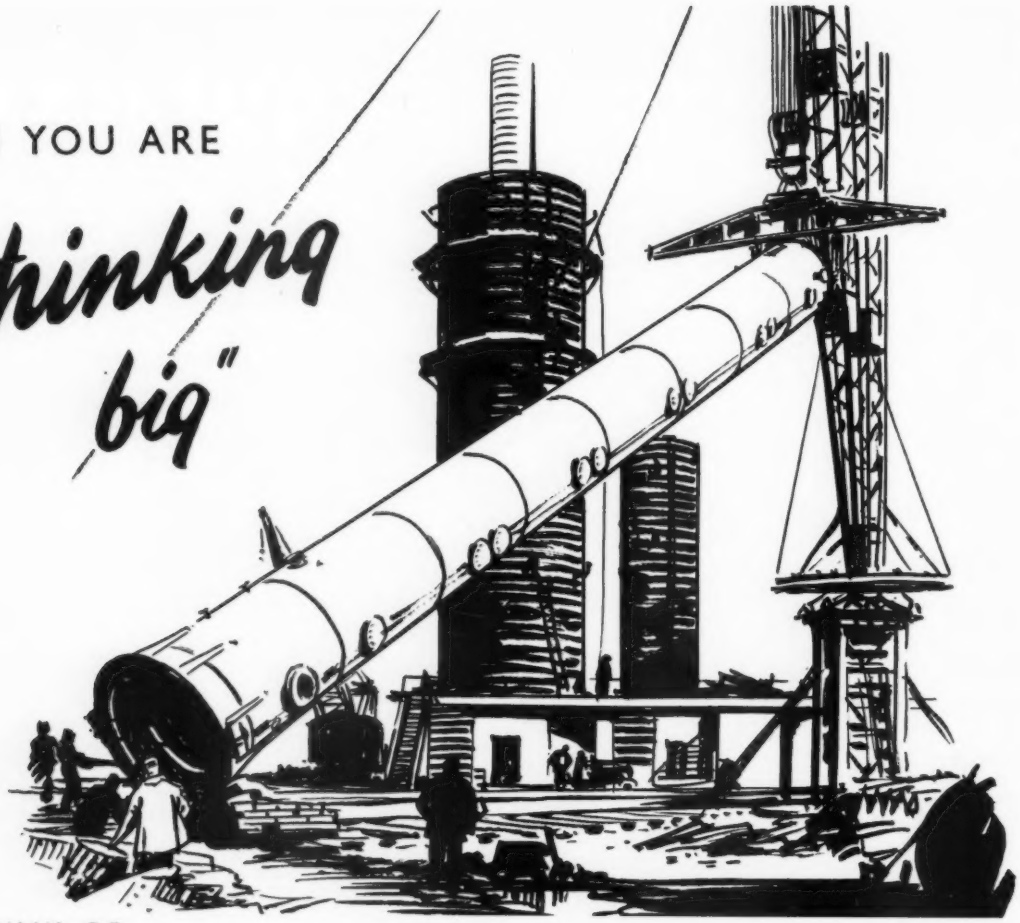

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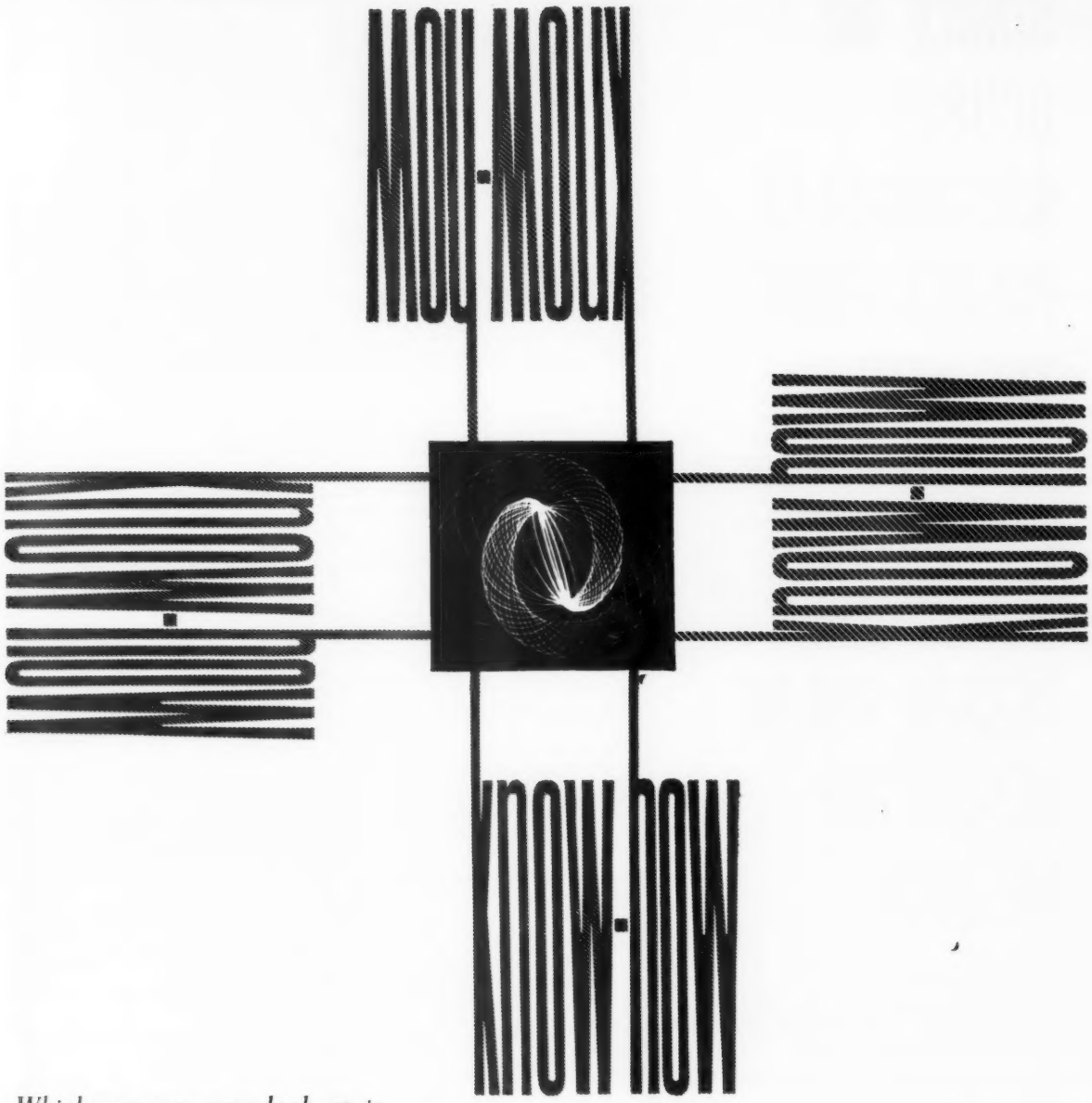

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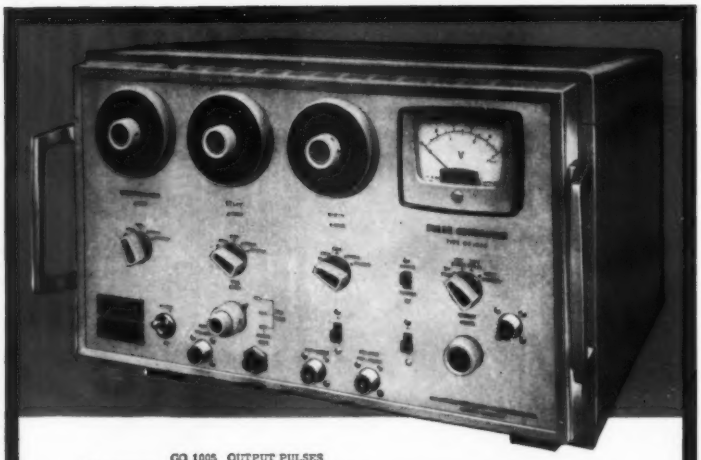

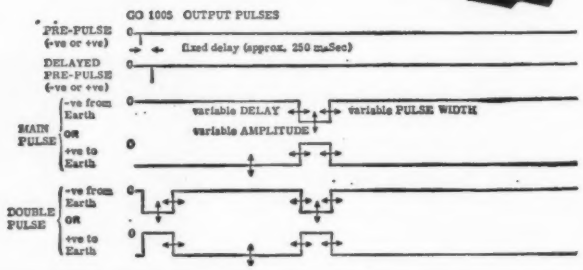

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Nuclear Power

FEBRUARY 1961 VOLUME 6 NUMBER 58

VIEWPOINTS *letters to the Editor*

University reactor delays

SIR: I fail to understand why our Roman friend *Gracchus* should give way to vagrant emotions and spontaneous stirrings of the spirit over delays in building a university reactor.

Why should it not take nearly two years before someone finally starts building a university reactor? Has *Gracchus* no idea of the amount of arduous and painstaking paperwork involved in Government procedure? Or of Parkinson's Law? Or of the intervention of distinguished personalities imposing their ideas late in the day? Has he forgotten that the amount of hard cash involved is comparatively small and as such is bound to be debated hotly in Government circles while millions are spent on Blue Streaks without a murmur or qualm?

Or is *Gracchus* taking pity on our bookish dons and taking up cudgels on their behalf because they apparently accept the present position without protest? After all, there hasn't been a breath of protest from them about the delays—understandably so, perhaps, in view of the controversy surrounding their application to university use.

London, W8 EDWARD E. RIVERS

Industry plays safe

SIR: I was interested to note some months ago a letter from Mr D. I. Johnston about industry's use of isotopes. (*The letter appeared in our September issue and, in brief, stated that the majority of British firms would take many years to accept the use of isotopes—Ed.*). I expected some reaction from persons more versed in the industrial uses of isotopes than I but was disappointed to see that apparently Mr Johnston's view was not challenged. I personally supported his view and this lack of response only confirms the experience that is, surprisingly enough, prevalent in the United States.

Here, despite the oft-repeated statement that American industry is willing to accept and exploit new techniques and ideas, there has been a comparative lack of activity on the part of industry to use these new techniques. Some industries, such as the oil industry, have gone wholeheartedly into this field but on the whole, I think it's fair to say that American industry seems to be as backward as British industry in this respect.

Perhaps industry still is under the misconception that there are hazards, costs and a lot of red tape involved in using tracers. This is not true and the generally conservative attitude is surprising when one considers the amount of interest shown in the USSR and East European countries.

In Czechoslovakia, for instance, over 200 laboratories, both industrial and scientific, use isotopes and significant work is being carried out in the development of organic tracer compounds—of which, I understand, over 70 types are being produced.

In addition, there is reported to be a vast amount of work being undertaken on the use of contained sources for industrial applications of which neutron probes for humidity measurements in the building industry and density measurements of cement mill sludge are but two examples.

In East Germany, too, great emphasis is placed on the use of isotopes and a new publication has appeared, '*Isotopentechnik*', which is devoted to research reports and descriptions of experimental results in the fields of applications of radioactive and stable isotopes.

Ann Arbor, Michigan R. G. FISHER

Direct generation of electricity

SIR: I would comment on two points in the article entitled 'The Direct Generation of Electricity' by B. C. Lindley in the July issue. Both points arise in the continuation, on page 82, of the paragraph beginning on page 81.

Firstly it is said that 'if the gas is expanded from pressure P_1 to pressure P_0 the corresponding temperature function $(T_1 - T_0)/T_1$ represents the maximum achievable efficiency'. Taking this to be a statement about the thermal efficiency of any thermodynamic cycle appropriate to a hydromagnetic generator, it must apply to the simple Brayton cycle without regeneration. But the statement then denies the improvement in thermal efficiency that results from regeneration, keeping the inlet and outlet temperatures unaltered. For the statement to be true, some qualification or explanation would seem to be necessary.

Secondly it is said that 'the temperature and pressure are constant in the generator duct so that the electrical conductivity does not vary'. Constance of both temperature and pressure would seem to be incompatible with the equations governing the gas flow, except in the highly unrealistic case of infinite electrical conductivity.

The argument is as follows:

Assuming that the cross-section of the duct is a slowly varying function of distance x from the inlet, the steady-state equations of conservation of momentum and energy and Ohm's law are, approximately:

$$1.\ \rho v \frac{dv}{dx} = -\frac{dp}{dx} - JB;\ 2.\ \rho v \frac{dH}{dx} = -EJ;\ 3.\ J = \sigma(vB - E);$$

where ρ is the gas density, v is the velocity, p is the pressure, J is the current density, B is the magnetic induction, E is the electric intensity (in the laboratory frame), σ is the electrical conductivity, and the stagnation enthalpy of unit mass of gas is: $H = \{\gamma/(\gamma-1)\}p/\rho + v^2/2$, γ being the ratio of specific heats. If pressure and temperature are both constant so also is the density; hence (1) and (2) become $\rho v \frac{dv}{dx} = -JB$ and $\rho v^2 \frac{dv}{dx} = -JE$, giving $v = E/B$.

Substitution for v in (3) gives either $J = 0$ or σ is infinite.

The first of these alternatives is trivial; and the second seems highly unrealistic in view of the crucial part played by the actual value of the electrical conductivity, and the considerable difficulty of achieving any significant conductivity at all.

Again some qualification or explanation would seem to be called for. Does the author have in mind an arrangement other than that described by the equations given here?

Reading, Berks G. C. SCORGIE

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OPINION

Industry and the isotope

THE WIDE SCOPE of the radioisotope field and the actual and potential industrial savings that could accrue, have been publicized ever since the application of radioactive techniques became a practical proposition. Since 1954, for instance, more than two international conferences a year (fourteen in all) have been held on research and technology in radioisotopes. This information has been generally circulated and is comparatively easy to obtain. Yet industry has still failed to take full advantage of the increased efficiency and savings that could come through the use of radioisotopes; and this is true not only of the UK but also of the USA, the Euratom countries, Australia and India where recently Dr Homi Bhabha stated that relatively little use was being made by Indian industry of radioisotopes.

If reluctance towards the use of these new techniques existed in all fields, there would be less cause to complain. But the medical world has been progressive in its outlook, finding in these new tools something of immense value which is now being applied in diagnosis, research laboratories and in hospitals throughout the world. Last year, hospitals took half the AEA's total sales (by number) of radioisotopes and in the Euratom countries, 70% of all individual consignments are for medical use. Against this, industry took only 15% of the AEA's 1959–60 sales.

In addition, prices are on the decline—cobalt-60 should fall to a new low when, as expected, it becomes available from the Bradwell and Hinkley Point civil nuclear power stations. Yet the AEA has a turnover of just over £1 million a year and only sold some 35,000 packages of radioactive materials in 1959–60—and the Authority is the world's largest supplier of radioactive materials.

Why then has industry failed to respond to this new method of increasing industrial productivity? One is inclined to dismiss this in one word 'conservatism'. But unfortunately there is no such simple answer. Fear and ignorance are undoubted factors; fear of radiation damage—which seldom arises in practice—and plain lack of familiarity with these new techniques. Added to this must be consumer's fear of radiation, linked to fall-out and suspicion that radiation can affect people in a way that scientists do not yet know about. This last factor may well prevent some firms from going in for the known advantages of radioactive techniques as potential customers may not place orders when they think a product contains radioactivity, no matter at what level this may be.

It is these factors that need analysing and breaking down. Positive steps have been taken in the UK with the setting up of the Isotope Information Bureau which together with the Authority's Isotope Advisory Service, Industrial Liaison Group and other services provided by the Isotope Research Division, gives this country a sound framework on which to build upon. It was particularly distressing then to hear that it was being suggested that the AEA's travelling exhibition 'Atoms at Work' should be scrapped—a retrograde step when so much needs to be done.

On the Continent, awareness is growing of the need for more publicity. The Euratom Commission has opened an information centre on radioisotope technology and is also prepared to supplement work being done in member countries to educate industry. It has also been suggested that there should be a centralized publicity campaign in member countries so as to make the maximum impact on industry.

Further steps can and should be taken. It is time a detailed survey was made of the reasons why industry has been slow in accepting radioisotope techniques; time, too, that another study of British industrial users of radioisotopes was made. On the basis of these results, a propaganda campaign could be planned and set in motion side by side with more general publicity efforts devoted to clearing up the overemphasis on the dangers of radiation and to stressing its benefits.

As a long term move, students should receive instruction in radioisotopes as part of their *basic* school science training. These students, familiar with the handling and safety of radiation techniques, together with the more fully trained graduates, could provide a powerful public educative force on the safety of the controlled use of radioisotopes. After all, the full value of radiation techniques has not yet been discovered, let alone exploited, and any steps that could be usefully taken to speed up their acceptance should be thoroughly explored.

We have to look to the future and the versatile radioisotope, already having its effect in science, medicine, agriculture and research, would justify the investment of more time, effort and money. As Professor Vasilly Emelyanov, head of the USSR Central Atomic Energy Administration, has pointed out when discussing radiation techniques: 'As things stand at present, it is hard to predict how the energy of fission will be utilized—either for power production or the production of chemical productions on the basis of radiation. It is very likely that electricity will be a by-product of the radiochemical industry'. The stage has now been set, to quote Dr Willard F. Libby, 'for an area of applied nuclear science in which the stellar role will be played by the versatile radioisotope'. It is now up to industry to seize its opportunities for there are some problems that can only be solved by the firms' engineers in consultation with AEA experts. The obstacles to the present widespread use of radioisotopes become relatively insignficant when balanced against the tremendous opportunities their use could bring.

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WORLDVIEW

the month in atomic energy

EUROPE

CEGB increases supergrid power

London A 400,000 V system is to be adopted by the Central Electricity Generating Board to reduce the number of high voltage transmission lines needed to meet increasing power demands.

The majority of existing 275,000 V supergrid lines, says the CEGB, were originally designed with an eye to future conversion to 380,000 V. Where increased transmission capacity is necessary, these will be reinsulated and used for the new high voltage. The power carrying capacity per double-circuit will thereby be raised from 1,200,000 kW to 2,000,000 kW.

For new main trunk lines, the Board plan to introduce a new design of tower, carrying four conductors per phase, as compared with two per phase on the 275,000 V lines. These towers will be about 20 ft taller than existing 275,000 V towers but this disadvantage will be outweighed by a further increase in power carrying capacity to 3,000,000 kW.

Orders for new equipment will be placed without waiting for operating experience with the 280,000 V experimental circuit between Monk Fryston and High Marnham which will come into service in 1962. The CEGB add that the first 400,000 V line should then come into commercial use in 1965. From then on, the new voltage will be introduced gradually to meet growing demand.

The CEGB also announced that record amount of new electricity generating plant was installed in 1960. The total additional electrical output capacity of this new plant was 1,935,000 kW, equivalent to 2½ million horsepower.

Altogether 21 turbo-generators and 22 boilers were installed in 14 power stations, four of which were new stations. Of the generating units, two more 200,000 kV units (installed capacity) were brought into service at High Marnham power station on the River Trent.

Danish research plans for 1961

Copenhagen A hot cell facility to serve both the DR2 and DR3 research reactors is to be built by the Danish Atomic Energy Commission. This follows consideration of a report prepared by Atkins & Partners of London, says the Commission's annual report.

Main interest in the Commission's research programme, the report states, has been centred on gas-cooled, water-cooled and organic-cooled reactors. These are considered the types most likely to be of use in Denmark. Participation in the Halden boiling water reactor project and the Dragon project covered two types.

• **Yugoslavia** The research reactor to be installed at the Josef Stefan Institute in Ljubljana will be a 1 MWt Triga Mark II.

The third is covered in the Commission's own work on a deuterium-moderated, organic-cooled reactor named DOR. Work on this started last year and is being continued. A new design has been produced for a 300-MWt reactor of the DOR type and modifications have been made to the cooling system of the DOR design project as well as a new proposal for the thermal shielding. Work has also begun on developing a fuel element based on UO_2 pellets and a water-loop has been designed to study pressure drop and oscillation conditions in various types of DOR fuel elements.

• **United Kingdom** The keel of Britain's second nuclear submarine is expected to be laid soon.

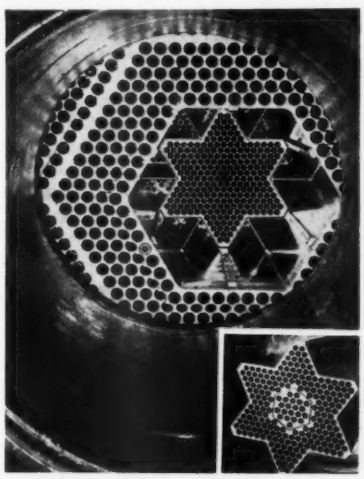
• **Poland** An agreement for scientific and technical co-operation has been signed with Italy.

• **Sweden** Work has started on ASEA's second nuclear power laboratory. It will be built in the company's present research centre.

GEC-APC merger

London Further progress is reported in GEC/Simon Carves and Atomic Power Constructions merger into the United Power Company. An official spokesman told *Nuclear Power* that the merger was definitely on. This followed reports of hard rethinking after the breakdown of the GEC-English Electric merger talks.

Equal holdings in UPC are expected to be held by the two groups with their design teams merging. Indications are that Crompton Parkinson Ltd of APC will drop out of the new arrangement. UPC's executives are said to be Mr A. Lindley, Chairman; Lord Coleraine, vice-chairman, and Col. G. Raby, managing director.



NEW DOUNREAY CORE A view through the aperture of the 2 ft 9 in diameter removable shield plug above the Dounreay fast reactor core. The inset at lower right is the type 'B' core tube nest which contains a removable centre section to allow the irradiation of experimental fuel elements

PETTEN CENTRE There is room for future expansion at the Dutch National Reactor Centre near Petten. The principal facilities of Reactor Centrum Nederland's central reactor laboratory, include a low flux reactor (LFR) and a 20 MWt pool type high flux materials testing reactor (HFR) which is due to go critical soon

Hirsch speaks on US-Euratom programme

Washington An insight into some of the highlights of the US-Euratom Joint Programme was given by M. Etienne Hirsch, President of the Euratom Commission at a speech here recently.

On the German AKS 150 MW OMR project, M. Hirsch, said the Federal Government had expressed readiness to cover part of the difference between conventional and nuclear costs, up to 100 million D-marks. However, as AKS was only incorporated for taking preparatory steps, a new company has to be formed for the construction of the project itself.

SEP, which groups all producers of electricity in the Netherlands, has also expressed continued interest in the Joint Programme but the time limit available had not yet permitted a final decision to be taken.

The West Berlin utility, BEWAG, desired to build a 150 MW reactor and the Mayor of Berlin had indicated that completion should be expected before the end of 1965 and not before the end of 1963 as indicated earlier.

• **Norway** The Norwegian Institutt for Atomenergi and the United Arab Republic's Atomic Energy Establishment have signed an agreement on co-operation.

• **United Kingdom** Building is to start in March of a nuclear school and laboratory at Portsmouth for the Royal Navy.

• **West Germany** Nukem has started up an automatic furnace for the production of uranium dioxide.

• **IAEA** A manual on the costing of nuclear power is expected to be issued soon. It will serve as a guide to countries considering the acquisition of nuclear power plants.

• **Finland** Agreements have been signed with the IAEA under which Finland will receive a US TRIGA research reactor and the enriched uranium needed as fuel.

• **IAEA** The report by the Oak Ridge team on the dosimetry measurements carried out at Vinca, Yugoslavia, has now been received. It is available from the Division of Public Information.

Decision soon on university reactors in the UK

London A decision is expected to be announced soon on applications by British universities for research reactors. Sir David Eccles, the Minister of Education, told the House of Commons recently that the applications involved for each reactor a capital sum of up to £250,000 plus annual maintenance costs. They also raised considerable issues of finance and principle and had to be assessed in relation to other requests in all fields of science for research grants to universities. A decision will be announced as soon as possible.

The universities which had applied for financial grants to cover the cost of building research reactors are: Birmingham, Imperial and Queen Mary Colleges, London, Manchester and Liverpool jointly, Southampton, and the Scottish Universities jointly with the Royal College of Science and Technology, at Glasgow.

European energy policies

Brussels Preliminary proposals for co-ordinating energy policies within the European Community have been submitted to the Council of Ministers of the European Coal and Steel Community. The plans were sent in by a working group consisting of representatives of the High Authority and the Commissions of the Economic Community and Euratom.

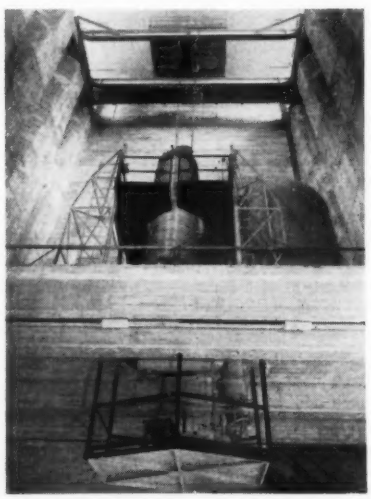
The general aim of the proposed measures is to bring down the price of energy in the Community to the most favourable economic level. As a first step it is proposed to harmonize commercial policies of member countries; lessen competition and reduce artificial price disparities.

New French fuel element plant

Paris A fabrication plant for fuel elements for heavy water reactors is to be built at St. Lobes, in the Gironde, by the Compagnie pur pour l'Etude et la Realisation de Combustibles Atomiques (CERCA). Construction costs are put at over 15 million new francs and production is expected to reach 250 tons of fuel elements annually by 1962. An increase to 400 tons yearly is expected in 1964.

Graphite delivered for FR-2 reactor at Karlsruhe

Bonn Graphite for the thermal columns of the 12 MWt heavy water moderated FR-2 research reactor at Karlsruhe has been delivered and is ready for assembly. The contract was placed with a group formed by Siemens-Plania, Chemische Fabrik Grieshiem, Merkingen/Augsburg, and the Graphitwerke Kroffmühl AG.



ITALIAN CENTRE The interior of the tower for the 3 MeV Van der Graaff accelerator at the recently completed Centro Informazioni Studi Esperienze (CISE) laboratories near Milan. The accelerator is being assembled

• **OEEC** Trade union experts representing 30 national trade union federations discussed the implications for workers of the increasing use of nuclear energy for peaceful purposes at a recent Düsseldorf meeting.

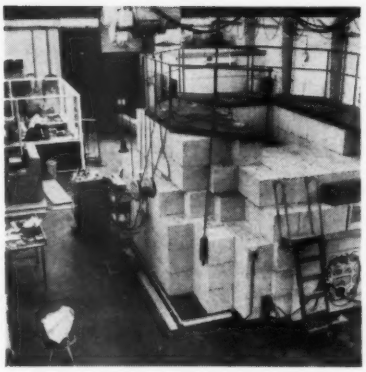
• **W. Germany** A total of 1233 users of radioisotopes were listed at the end of 1959. These figures do not include users of radium, uranium and thorium compounds.

IAEA studies Finnish prospects

Vienna A further series of studies for assessing more fully the prospects of nuclear power in Finland is recommended by a report jointly released by the IAEA and the Finnish Atomic Energy Commission.

While the report, 'Prospects of Nuclear Power in Finland', is limited to specific conditions in that country, it is hoped that it will be useful to other countries as well because the method followed, the factors discussed and some of the data are sufficiently general to be useful to a number of countries.

For 1970, one basis of comparison costs shows that under certain conditions a 250 MW nuclear plant operated with a load factor of 80% might well become competitive.



DUTCH RESEARCH REACTOR A view of the low flux research reactor (LFR) at the National Reactor Centre at Petten shortly before its construction was completed. The 10 kW Jason type reactor was designed by Hawker Siddeley Nuclear Power Company

• **United Kingdom** Sir John Cockcroft and Sir Roger Makins, chairman of the AEA, attended the formal inauguration of the Canada-India reactor recently.

• **France** Two contracts have been placed by Euratom with the Grenoble research centre; one is on the study of heat exchangers and the other to find a substitute for terphenyl.

Decision delayed over Swedish boiling water reactor

Stockholm A decision over the two offers to build the 50 MW boiling water reactor for the Simpevarp power station is expected to be delayed for two months. Reason for the postponement is that more time is needed to consider the tenders put in by ASEA and NOHAB in collaboration with the US General Electric Company and by the Kockums Mekaniska Verkstad and Tekniska Byggnadsbyram companies in collaboration with Allis-Chalmers (see *Worldview*, September 1960, p 85).

SELNI site purchased

Rome A contract for land for the proposed SELNI pressurized water reactor station has been signed by the Societa Elettronucleare Italiana and the Commune of Trino Vercellese (Piedmont). The site is on the left bank of the River Po and covers an area of 600,000 sq. metres.

The SELNI plant is scheduled for a 1964 start-up and will use a Westinghouse reactor. Among the companies interested in the project is Electricite de France which is taking 8% of SELNI's capital (see *Worldview*, January 1961, p 58).

OVERSEAS

Australian progress on the HTGC system

Canberra Work is going ahead steadily in Australia on the High Temperature Gas-Cooled reactor system. The present programme, says the Australian Atomic Energy Commission's annual report, involves intensive research into nuclear materials—more particularly uranium, thorium, beryllium, beryllium oxide, carbon dioxide and graphite.

The report states that 'the most promising fuel elements for the HTGC at present appear to be those incorporating beryllium, uranium and thorium. The spent fuel elements withdrawn from a power reactor will contain valuable residues and these must be recovered. The chemical processing of fuel elements incorporating beryllium has not been studied at other countries and is therefore the subject of research at Lucas Heights; the results are important to the choice of fuel and in the determination of the economics of a reactor system'.

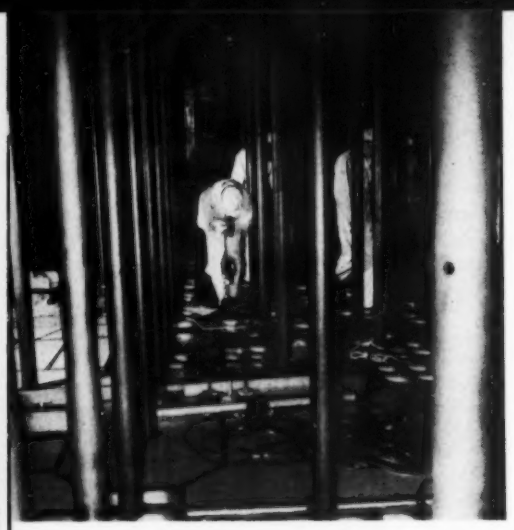
Research on fabrication properties of cermets is proceeding as an introduction to larger scale production of HTGC fuel elements. Further progress was made in developing techniques for making graphite fuel compacts containing up to 60% by weight of heavy metal. The physical properties of the compacts before and after sintering to 2600°C were determined and it was shown that hydrolysis of the sintered compacts was due solely to the presence of thorium dicarbide. Techniques for handling the compacts to overcome this problem and the production of compacts of graphite and metal oxides are in progress.

On irradiation research, the report says that prototype fuel elements of both beryllium and beryllium oxide matrix were inserted into the research reactor HIFAR and appeared to be behaving satisfactorily at high temperatures. They will be irradiated for about six months. A series of experimental rigs containing beryllium specimens was supplied by the UKAEA and is being irradiated in HIFAR under contract. In addition, an experimental rig containing specimens of fissile material to be irradiated for the General Electric Company was successfully commissioned and irradiation in HIFAR began in February, 1960.

On the market for uranium, the report says contracts with the Combined Development Agency, the UKAEA and the USAEC safeguard most producers in leading countries for the next few years. Thereafter the market is expected to be extremely competitive until the 1970's. Current market opinion overseas is that during most of the current decade, uranium producers will be able to compete successfully only if they can make a profit at a price of $5 per lb for uranium oxide or at least maintain production at a price of $4. The report adds that there is a widely held opinion that an expansion of uranium production will be required after 1970.

• **Formosa** A schedule for the construction of the country's first nuclear power station—a medium-sized plant scheduled for 1968 operation—has been worked out by the Taiwan Power Company.

• **USSR** Future power in the Soviet Union will come more from fusion predicts the President of the Soviet Academy of Sciences. He was writing a New Year round-up of Soviet progress in science for *Pravda*.



BERKELEY PROGRESSES This recent picture taken at the Nuclear Power Group's Berkeley nuclear power station shows an electromagnet being used to remove metallic particles after welding of trumpets inside the No. 1 pressure vessel. Checked fuel channels are covered by plastic boards (foreground)

132 US utilities now in atomic energy

New York Substantial gains in their nuclear power programmes were made by US electric companies in 1960 says a year-end statement from the Edison Electric Institute. At the end of 1960, the report says, 132 electric power companies were taking part in one or more of 26 major projects for the development and construction of atomic power plants and for major research, development and study projects. This broad programme involved a total investment of over $650 million.

Five company nuclear power stations were in operation and two more were expected to come into operation in 1961, bringing the nation's total capacity to about 760 MW by the end of 1960.

Proposals asked for nuclear rocket engine

Washington A request for research and development proposals for a nuclear rocket engine will be sent to a number of manufacturers, says the National Aeronautics and Space Administration. This follows the successful ground test of the KIWI-A 3 reactor, the third to be built and tested under the rocket propulsion programme (Project Rover).

Meanwhile, a contract for a test cell in the Rover test area has been awarded to the Actron Division of Aerojet General Corporation. This test stand will consist of a multi-storied structure for supporting an experimental nuclear reactor in a down-firing position. The test facility in use is designed for up-firing reactor experiments.

• **Canada** Production of U-308 in 1960 totalled just over 25 million lb according to the Dominion Bureau of Statistics.

Israel builds a second reactor

Tel Aviv The existence of a second Israeli reactor was officially disclosed by Mr Ben Gurion, the Israeli Prime Minister recently. This followed earlier denials in London and Washington that such a reactor existed (see *Worldview*, January, p 60). Unofficial reports put the cost at $10 million.

Mr Ben Gurion made his statement in reply to a question from an Israeli Member of Parliament. He said that for the development of the Negev desert, regarded as a main objective in the next decade, a wide range of scientific research was necessary.

For this purpose, an institute had been established at Beersheba for research in arid zones and a reactor was being built with a capacity of 24 MW. This was intended to serve the needs of industry, agriculture, health and science and would give Israeli technicians experience needed to build a nuclear power station.

The new reactor was similar to the Canada-India reactor and was being built by Isaeli technicians. It would serve for the construction of a nuclear power station within a period of 10–15 years.

No mention was made of French aid by Mr Ben Gurion but an official statement from Paris said that France had been giving Israel technical assistance in the construction of an atomic pile which operated with uranium and heavy water.

In the House of Commons, Mr R. A. Butler, Leader of the House, said that the French Foreign Ministry had recently declared that all necessary dispositions had been taken to ensure that the Israeli installations, made with French assistance, would be used exclusively for peaceful purposes. He had been informed that the site south of Beersheba was not so advanced that it could be used for military purposes.

AEC relents on gas centrifuge

Washington The AEC now proposes to allow industry access to restricted data on the gas centrifuge. This extension of the access permit programme would permit industry to use private funds and to retain the benefits of its work in this area.

According to an AEC statement, industry has informed the Commission that it believes there is substantial commercial potential in the use of the gas centrifuge to provide fuels for nuclear reactors.

The AEC has been conducting research and development work on the gas centrifuge and its planned programme includes these three major projects: (1) continuation of basic research underway at the University of Virginia; (2) experimental operation of small groups of machines incorporating present technology being done under contract at Oak Ridge and (3) a programme under which private companies will be invited to submit proposals to perform development work under contract for the AEC. This would be for developing advanced models of the gas centrifuge.

A violent storm blew up recently (*Worldview* Nov) over German work on the gas centrifuge method for separating heavy isotopes which can be handled in a gaseous form and developments there are now classified. Because of its potential use in the production of weapons grade material, much of the information on it is classified.

• **United States** The first of the eight PWR's in the nuclear aircraft carrier, *Enterprise*, has gone critical. It is the first reactor to achieve criticality in an American surface ship.

• **South Africa** Exports of nuclear materials in the first eleven months of 1960 were worth £43 million against £45 million in the same 1959 period.

• **United States** A second core for the AEC's Gas Cooled Reactor Experiment at the National Testing Station in Idaho recently produced design power of 2 MWt.

• **Argentina** Samples of concentrated uranium from the Cordoba Province have been shipped to West Germany for analysis.

• **South Korea** The TRIGA reactor at Seoul is expected to start operations soon, says the Atomic Energy Commission.

• **United States** A public hearing has been held on the 60 MW light water Plum Brook test reactor by the USAEC. The reactor will be operated by the National Aeronautics and Space Administration.

• **United States** The initial shipment of fuel elements for the *NS Savannah* has been delivered by the Babcock & Wilcox Company.

• **South Africa** Potchefstroom University is to buy a Cockcroft-Walton accelerator from Cambridge.

• **Argentina** A uranium 'price war' because of falling demand is expected, said delegates from 16 countries at an 'Atoms and Space' meeting in Buenos Aires.

Indian isotope progress

Bombay Progress made by the Indian Atomic Energy Commission in the use of radioisotopes was outlined by Dr H. J. Bhabha at the opening of an IAEA sponsored symposium held here recently.

The chairman of the Commission told the assembly that when the Canada-India reactor (CIR) went into full production, India would become one of the largest producers of radioisotopes in the world. Not only had the production of isotopes increased in India but there had also been a remarkable rise in the use of isotopes in research and in medicine. But relatively very little was being done by industry in India.

Among the projects Dr Bhabha mentioned was one for increasing the quantity and improving the quality of Indian silk by using radiation as a means of killing the silk worm in the cocoon in place of the conventional method.

Power production proposed for Hanford

Washington The possibility that electricity will be produced from Hanford New Production Reactor, originally proposed as a plutonium producer only, is to be discussed by the Joint Congressional Committee on Atomic Energy and the US Congress. This follows the release of a new report on the economic feasibility of by-product electric power production at the NPR by R. W. Beck & Associates of Seattle.

The report concludes that dual-purpose operation could be economically advantageous to the government under several different combinations of assumptions. One of the most favourable conversion schemes involves the addition of approximately 700 MW of electrical generating capacity to the plant. The conversion cost is estimated at $100 million by the Beck report.

The NPR is under construction at Hanford. The initial authorization totalled $145 million and covered the estimated cost of the basic reactor plus the inclusion of design features in the reactor which would permit the use of reactor heat energy for the generation of by-product electrical energy. It is scheduled for completion in 1962 but two years of tests will follow so the earliest date for power production is expected to be 1964.

Earlier studies were made on the use of the reactor for electrical generation but these were classified in part or wholly as the information they used related to military plutonium requirements.

• **United States** The Shippingport blanket, as of August 30, 1960, received an exposure of approximately 2600 megawatt-days per ton of UO_2 average or 12,400 mwd per ton maximum. This is said to be the highest exposure achieved in large batches of uranium oxide fuel.

• **Australia** The rate and pattern of silt flow from the Hunter River into Newcastle Harbour has been successfully established by the AAEC through the use of tracers.

Japanese ore-carrier plans

Tokyo The Japan Atom-Powered Ore Carrier Research Group has made public a draft plan for the construction of a 64,000 dwt ore carrier powered by a 63 MW indirect cycle boiling water reactor. This is the first design study made in Japan of a nuclear ore carrier. Under the plan, the reactor would be built mainly in Japan and the vessel completed by 1968.

The members of the group are the Nissan Steamship Company, the Japan Steel & Tube Company, Hitachi Ltd and Marubeni-Iida Company. The vessel would be used for shipping copper ore from Chile to Japan and is thought to be an economic proposition.

New power efficiency concept

Mountain View, Calif. A new concept to increase the efficiency of power reactors is to be investigated by Advanced Technology Laboratories, a division of American Standard. Under the terms of a contract awarded by Euratom and the AEC, the division will carry out research on the use of ultrasonic vibrations to raise permissible heat transfer rates in nuclear equipment using boiling liquids.

Yankee produces electricity

Washington After ten weeks of testing since it went critical, the Yankee Atomic Electric plant at Rowe, Mass., produced its first electric power. Through gradual power increases, the plant is expected to reach a planned 110 MW soon. The reactor was supplied and designed by Westinghouse Electric Corp. and preliminary construction work started in October 1957. The plant went critical in August 1960.

ARGONNE SYNCHROTRON Some of the structural steel for the circular-shaped building to house the Zero Gradient Proton Synchrotron (ZGS) at the Argonne National Laboratory is seen in place. The ZGS, when completed in 1962, will be used to find out more about the basic nature of matter

WORLDVIEW

OMR proposals invited by AEC

Washington A nuclear power demonstration project incorporating a prototype 50 MW organic cooled and moderated reactor may be built by the USAEC. The Commission has invited 'expressions of interest from co-operatively and publicly-owned utilities' in the proposal.

The utility taking part would be expected to provide, as a minimum, the site and conventional facilities; to operate the plant for five years at least, and to purchase steam from the reactor. The nuclear steam supply system, including the reactor, would be financed principally by the AEC.

The request represents the first of two steps. If expressions of interest show good prospects, a further request will be made for detailed proposals. At present, three OMR projects are built or planned in the US. One is the Organic Moderated Reactor Experiment (OMRE) in Idaho in operation since 1957. This is providing technical information for an 11·4 MW OMR at Piqua, Ohio. The AEC is also building a flexible experimental facility at the National Reactor Testing Station, Idaho, known as the Experimental Organic Cooled Reactor. This 20-40 MWt facility is being designed by the Fluor Corporation Ltd with Atomics International performing the nuclear design.

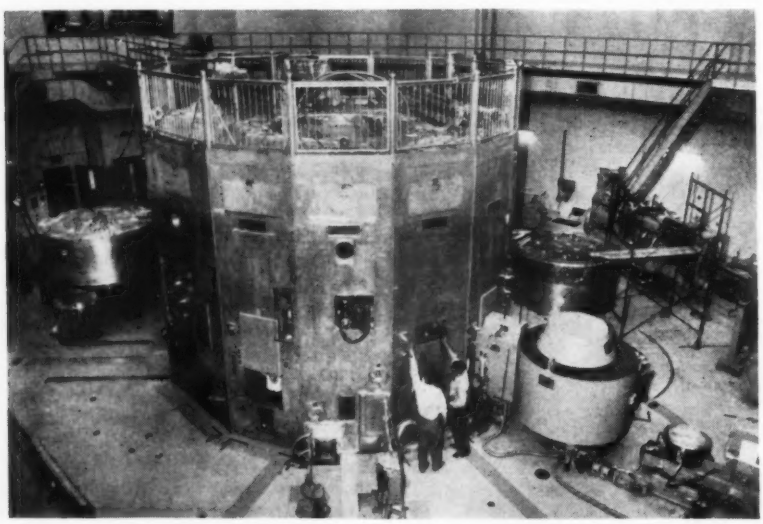
Latvian research centre planned

Moscow A research centre, to be built round the research reactor now under construction at Salaspils, 12 miles from Riga, will have a linear accelerator block and a building for a proton accelerator. Provisions are also made for the building of a physical technology section for the study of radioactive substances and radiations. Completion of the project will enable the Latvian Institute of Physics to carry out a full research programme.

In addition, a research reactor at the Physics Institute of the Latvian Academy of Sciences, the first of its kind in the Baltic Republics, is nearing completion.

Meanwhile it was announced that Soviet power generation in 1961 was expected to exceed 327,000 million kW hours. This was disclosed by Vladimir Novikov, vice-chairman of the USSR Council of Ministers and chairman of the USSR State Planning Committee.

He added that it was planned to increase the capacity of the power industry mainly by building thermal power stations. New capacity totalling 7·8 million kW would be put into operation within a year. In addition, work would start on a number of large projects whose total capacity was 15·5 million kW.



SECOND JAPANESE REACTOR An interior view of the JRR-2 research reactor designed and built by American Machine & Foundry Company for the Japan Atomic Energy Research Institute at Tokai-Mura, Japan. The $1·5 million reactor is the largest in the Far East and is the heart of the Institute's 40-building research centre. The Institute employs about 1200 people at its headquarters in Tokyo and at the research centre at Tokai-Mura, conducting a wide range of research, testing and experimentation

• **Australia** Industry is being urged to make wider use of radioisotopes and nuclear equipment. A special committee on isotope promotion is to be set up.

• **Japan** A special division for radiation chemistry is to be set up at the Japan Atomic Energy Research Institute.

• **South Africa** Talks have been held between the Combined Development Agency and the Atomic Energy Board on future sales of uranium oxide.

• **Australia** Tracer tests to determine the pattern of tidal movements have been carried out in Hospital Bay, Southern Tasmania.

AEC changes BWR decision

Washington The AEC recently reversed one of its decisions when it announced that the Allis-Chalmers proposal for a 50 MW Improved Cycle Boiling Reactor (ICBWR) had been selected. In the middle of 1960, the contract for this Los Angeles-Pasadena plant in California was awarded to the US General Electric Co.

The plant will be a prototype for a 300 MW reactor incorporating features aimed at reducing power costs. Under the proposed arrangements, two municipal utilities will provide the plant site at Haskell Canyon, Los Angeles County, and the turbogenerator facilities. They will operate the facility for the AEC for not less than five years and purchase the steam produced by the reactor.

Under the terms of the proposal, Allis-Chalmers will design, fabricate, construct and test operate the reactor, furnish the first core and spare fuel elements and provide training for operating personnel. The ICBWR is planned for completion in early 1964.

No mention was made by the AEC of its selection in June 1960 of the GE Company's proposal. According to American sources, the decision was reversed after protests from the other bidders and the documents re-examined. It was then discovered that there had been an error in the evaluation of the original bids.

Successful SNAP reactor tests

San Francisco A prototype of the first reactor for outer space has successfully completed operational ground tests. Lt-Col G. M. Anderson of the US Air Force said the SNAP experimental reactor had completed a one-year test programme which verified significant performance characteristics necessary to design the final flight reactor.

The reactor was developed by Atomics International as part of the AEC's Systems for Nuclear Auxiliary Power (SNAP) programme.

• **Australia** New underwater equipment for machining irradiated fuel elements has been commissioned at Lucas Heights.

• **Brazil** The TRIGA reactor at the University of Minas Gerais, Belo Horizonte, has gone critical.

• **United States** Site work has started on a radiation engineering laboratory at the Brookhaven National Laboratory.

Steam turbine completed for Soviet PWR station

Moscow The first 70 MW steam turbine for the 420 MW Voronezh PWR station has been built at the Kirov Works, Kharkov. Two more turbines of equal capacity will be built for the two reactor station this year.

The recently completed turbine will work on saturated steam under a pressure of 29 atmospheres to a speed of 3000 rev/min. It will be automatically controlled.

New Oak Ridge reactor

Oak Ridge A small research reactor, to provide short bursts of radiation for biomedical and health physics research, is to start up in April at Oak Ridge National Laboratory.

Called The Fast Burst Reactor (FBR) project, the reactor will consist mainly of a core of uranium molybdenum alloy without shielding or moderator. Radiation exposure will be very small outside the limited access area and the reactor will be located in a hollow surrounded by hills of sufficient height to provide adequate shielding from surrounding areas. The control building will be located about 800 ft away, behind a ridge.

• **USSR** Fuel elements for a critical assembly to be built in Finland have been offered by the Soviet Union through the IAEA.

• **Japan** A radioisotope laboratory has been built for the Institute of Physical and Chemical Studies (Riken).

BROOKHAVEN CYCLOTRON An unusual picture of the 18-inch cyclotron at Brookhaven National Laboratory with its 30-ft beam pipe in the foreground. This pipe makes possible the use of an intense beam of neutrons by focussing the 3 million electron volt protons from the cyclotron on to a target centred in a room of 40 cubic feet. A steel grating floor, 15 ft above the concrete floor, provides support for instrumentation in the vicinity of the target

Reactor accident at Idaho Falls

Idaho Falls Efforts are still continuing to determine the exact cause of the explosion at the USAEC's National Testing Station which caused the death of three US military technicians. The accident occurred on January 3 inside the building housing the US Army's Stationary Low-Power Reactor No. 1, a prototype small power reactor for supplying heat and power for isolated military posts. An investigating committee is looking into the cause of the accident. The AEC, in the meantime, has ordered a survey of all its licensed reactors as a result of the explosion.

An AEC statement said: 'An accident of undetermined origin involving a severe explosion fatally injured three men shortly after 9 pm Tuesday (January 3) at the National Reactor Testing Station. The fatal accident, the first of its kind in the 11 year history of the Idaho site, occurred at the Stationary Low-Power Reactor No. 1 in the Army reactor experimental area.

'It has been verified that the three victims, all military personnel, were the only people on duty at the time. Automatic heat detector alarms sounding in the three site fire stations gave first warning of the accident. High levels of radiation were found in the immediate area of the reactor and the reactor building. . . .'

The AEC says that there is strong though not conclusive indication that a nuclear excursion was involved in the accident. It could not yet be established whether there might have been an explosive chemical reaction. The level of radioactivity when the rescue workers arrived was at level of 1000 roentgens (a level of 450–600 is lethal). A preliminary examination of the bodies showed that multiple injuries at the time of the accident were enough to cause death. It is also understood that radioactive material had been blown into the bodies by the force of the explosion and that the reactor apparently 'blew its top'.

No details of the damage have yet been released and the high level of radiation continues to hamper investigation work. A television camera was being placed in the reactor building to survey the damage.

Cause of the accident is suspected to be a mistake with the cadmium control rods as the three men were continuing the job of connecting up the control rods preparatory to restart-up of the reactor after 10 days of shutdown for the insertion of power distribution measurement wires.

The SL-1 is a direct-cycle boiling water reactor of 3 MWt, moderated and cooled by light water. It was formerly known as the ALPR, and is designed to produce 200 kW of electricity and 400 kW of space heat at an operating pressure of 300 lb/in². A package plant, it is designed to be built on any terrain; no excavation is necessary for the reactor shell. Ordinary gravel is used for biological shielding within the reactor building. There are five cross-shaped control rods of cadmium and X-8001 aluminium-nickel alloy. The reactor is housed in a circular, continuous-welded steel tank.

SL-1 rescue operations

January 3	
9.01 pm	Automatic alarm received; personnel radiation monitor a mile away gives off alarm and remains erratic for several minutes.
9.10 pm	Fire engines and security forces arrive. Unusually high radiation levels reported in reactor building.
9.17 pm	Health physicist arrives. Meets radiation fields of 500 mr to 10 r per hour.
9.35 pm	Two more health physicists arrive. Meet 200 r radiation field at stairs of reactor building and 500 r per hour on reactor floor; some evidence of damage.
10.35 pm	Entry on to reactor floor. Two men seen; one moving. Withdrawal and re-entry by further team and alive man removed.
10.48 pm	Third man located in ceiling above the reactor—dead.
11.14 pm	Man removed from SL-1 pronounced dead. Rescue operations suspended.
January 4	
6 am	Decontamination of body removed from SL-1. Readings 400 r at head region, 100 r at feet and 200–300 r over the remainder of the body.
7 am–11 pm	Second body removed from area where radiation levels estimated at 750 r per hour.
January 9	Third body removed. Rescue operations completed.

Irradiation times may be only a few seconds

Reactor facilities for the production of radioisotopes

by R. WEST, Technical Manager, Radiochemical Centre, Isotopes Production Unit, AERE, Harwell

THE REACTORS used by the UKAEA for making isotopes employ both permanently installed and removable types of equipment. The removable assemblies are generally used for bulk irradiation of the longer lived isotopes supplied from stock. They are loaded and unloaded when the reactor is shutdown, either by transfer to a remote handling facility or by withdrawal from the reactor directly into a mobile handling cell.

The permanently installed equipments are more complex. They are designed for the loading and unloading of individual specimens into selected positions at any time, while the reactor is operating, and without significant disturbance to other materials or to the control of the reactor. These are used to provide a prompt service to users of the shorter lived isotopes.

The two principal reactors used are: BEPO which has a large core of natural uranium fuel, a graphite moderator, air cooling and a central thermal neutron flux of $1{\cdot}5 \times 10^{12}$ n/cm² s; and DIDO which has a small core of enriched uranium, a D_2O moderator, a small graphite reflector and a maximum thermal neutron flux of 10^{14} n/cm² s.

Design and safety

To minimize neutron losses, structural assemblies are constructed of light-weight, low absorbing materials such as alloys of aluminium, zirconium and magnesium. Formation of spurious gamma-ray emitters in structures is avoided by the choice of suitable grades of material. This reduces shielding problems on removal.

The packing arrangement for samples in an assembly is decided by the acceptable level of diminished yield arising from self-shielding and mutual shielding to neutrons, as well as gross flux depression effects. Samples are therefore limited in total neutron absorption cross-section and suitably spaced from one another. For example, a 10-g cylinder of cobalt metal will realize less than 50% of the full yield owing to self-shielding, and cause a local depression in the neutron flux, extending to about 2 cm from the surface. Arrangements are often decided from experimental monitoring, using long wires and scanning measurements.

While the reactors used have moderator temperatures of less than 100°C, local heating in structures and samples can occur in the higher fluxes through 'nuclear heating'. This is the sum heating effect of particle and radiation absorbed energy. For example, in the core of DIDO, heating can occur of the order of 2 W/g for pure aluminium and about 5 W/g for cobalt metal. Cooling is provided where necessary by demineralized light water or gas circulation and in certain cases assemblies can be placed in the D_2O moderator giving direct heat removal.

It is important to avoid trapped air in the high flux assemblies as the natural argon content will, for example, build up to about 400 mc/l of air at saturation in 10^{14}n/cm²s and so constitute a special hazard. With an air cooled reactor, the rapid and continuous flow avoids this problem, but in others it is necessary to purge with CO_2 and seal when loaded into the reactor.

Safety requirements guard against harmful effects to the reactor, the equipment or the samples; it is important to avoid using materials that could aggravate an incident occurring in the reactor, e.g. materials liable to react at elevated temperatures.

Schedules of acceptable substances and quantities for irradiations in specified equipments, are prepared for each of the reactors. Standard screw-top cans of high purity aluminium are used for most irradiations; there are three principal sizes—type A, 30 ml; type B, 6 ml; and type C, 3 ml. The two smaller cans may be used as secondary inner containers. Laminated aluminium foil washers render the cans powder-tight under normal conditions. Where some gas evolution may occur under irradiation, it is preferable to allow this to escape into the reactor gas purging system rather than build up a pressure.

For gas sealing, or special containment, silica or brazed aluminium are normally used; silica frits are employed also when gas venting is desirable. While most plastics deteriorate rapidly under irradiation, polythene containers will usefully last for about a week at 10^{12} n/cm²s at modest temperatures. Crumpled aluminium foil or silica wool are often used as packing for fragile specimens and

Flux conditions in

BEPO irradiation belts

thermal flux, n/cm²s	10^{11}–$1{\cdot}3 \times 10^{12}$
fast flux, n/cm²s	3×10^{9}–2×10^{11}
temperature, °C	23–65
γ-flux, r/h (E av 1·3 MeV)	$2{\cdot}5 \times 10^{5}$–$1{\cdot}8 \times 10^{6}$

DIDO Honeycomb units

thermal flux, n/cm²s	5×10^{11}–4×10^{12}
fast flux, n/cm²s	3×10^{7}–$3{\cdot}4 \times 10^{9}$
temperature, °C	70–135
γ-flux, r/h (E av 1·6 MeV)	10^{5}–3×10^{6}

foamed polyurethane is useful within limits of time, temperature and irradiation.

Irradiation belts

There are five endless belts traversing the BEPO reactor in horizontal holes four inches square (Fig. 1). Some belts are double sided in respect of sample holders, and can be wound in either direction for the loading and unloading of materials. Others are single sided with a return cable.

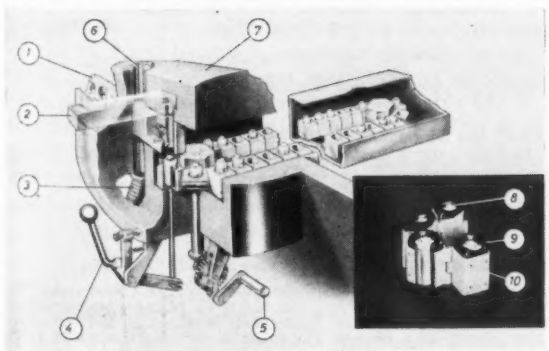
Each of the double sided belts can accommodate up to 300 samples in A-type isotope cans with a spacing of two inches between centres. The cans sit vertically in graphite cups which are held in a magnesium-zirconium alloy extrusion, acting as a support box and hinge-plate segment of the belt.

Samples are loaded by dropping into a shielded sliding drawer which is moved over the selected belt segment and the can released to fall into position. The unload follows the reverse procedure, the sample can being ejected from the belt with a plunger into the sliding carrier and then released into a discharge tube leading to a lead transport container underneath the unit.

Active samples can often be safely reloaded by transfer with handling tongs from a carrier placed as close as possible to the load-tube. Also a mobile pneumatic can transfer system is used for multiple reloadings but this is only suitable for specimens that will tolerate rapid motion and some impact on arrival.

Belts may safely be rotated and samples loaded and unloaded while the reactor is in operation with small effect upon the reactivity. However, the Reactor Duty Engineer Control Officer is consulted before any movement is allowed; after use, belts are promptly returned to the in-pile position to minimize interference with other irradiations.

(Left) operator using BEPO isotope irradiation belt (Below) diagrammatic arrangement of the belt (Fig. 1)



Operator loading samples into the BEPO self-service rabbit selector unit. The pump unit is at the bottom right (Fig. 2)

A half of one belt is reserved for samples having a maximum flux or temperature limitation. During load and unload this belt is wound out in one direction only so that these samples are moved away from the reactor core and not towards it.

Self-service 'Rabbit'

This is installed in BEPO for short irradiations, down to a few seconds in duration (Fig. 2). One irradiation may be carried out at a time, and the sample position is near to the pile centre at a flux of about $1{\cdot}3 \times 10^{12}$, in an ambient temperature of about 90°C.

Sample cans of up to $\frac{7}{8}$ in dia. by $2\frac{1}{2}$ in long are housed in a nylon loaded bakelite bobbin which is loaded into a selector box near to the pile control face. From here, samples are blown through a tube by air, into and out of the pile, at the turn of a control lever. The bobbin returns to a shielded box where short-lived activities are allowed to diminish before removing the sample. The bobbin material is chosen to give rise to a minimum of spurious short-lived activities; however, the eventual deterioration under irradiation, together with the mechanical shocks received, causes cracking, and bobbins are replaced periodically.

Further rabbit installations in BEPO and in DIDO are part of a joint network coupled to a number of laboratory control stations on the site. These are used for research with short-lived isotopes.

Honeycomb units

At present three of these units occupy 6 in horizontal holes in the reflector of DIDO (Fig. 3). Each unit holds 70 A-type isotope cans any one of which may be loaded and unloaded independently with the reactor at power.

The units consist of a row of ten cylindrical magazine chambers rotating on a central shaft. Each magazine has seven sample chambers plus one straight-through transport passage. By selective alignment, samples are blown through the transport tube segments to the chosen rest position, and subsequently returned by the same passage for unloading.

Samples are loaded manually with a push rod into the shield plug of the assembly from where they are blown

into position. The unload sequence is to blow out into a holding position in the shield plug, where short-lived activities are allowed to decay, then to discharge manually with a pull-rod into an external tube which guides the sample, by gravity to a shielded transport container.

As any trapped air in the unit would build up some active argon-41 (half-life 1·82 h), the whole assembly is sealed and purged with CO_2 which is also used for blowing the cans; sealing is also necessary to avoid the hazards of activated dust disturbance that arises with the use of a pneumatic system.

Due to nuclear heating in the structure materials, the temperature in the unit reaches a maximum of 135°C, compared with about 90°C in the surrounding graphite reflector. At present, each sample is limited to a heat production of about one watt. The flux gradient is steep, and over the length of an irradiation can varies between 25% to 100% change within the reflector. The minimum sealing requirement for samples in this facility is double containment in standard isotope screw-top cans.

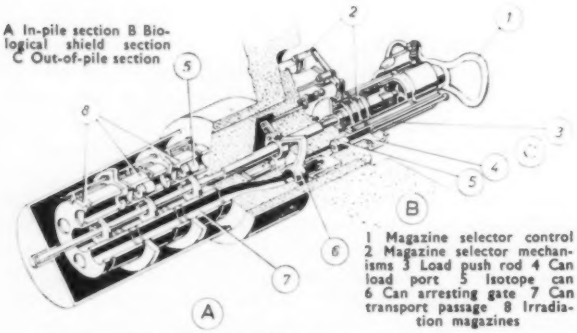
A higher flux unit of similar design is planned for a 4-in horizontal hole, and is expected to provide fluxes up to 5×10^{13} (fast: 10^9–2×10^{12}) for specimens in the B-type isotope can. Provision is made for gas cooling, and under test is a small external handling box that will facilitate the re-loading of active materials, or the transfer from one position or unit to another.

Bulk irradiations

TE holes BEPO A number of $4\frac{1}{4}$ in dia. vertical holes enter from the top thermal column, passing into the core below the centre-line of the reactor. These are used to accommodate aluminium buckets 15 in long, normally with twelve per hole. Typical uses are for the irradiation in bulk of sulphur for P-32 production and Tellurium dioxide for I-131 production. The buckets rest one on top of another in the reactor, and are loaded and unloaded with the use of external equipment (Fig. 4).

Samples are unloaded into the rotary magazine, which holds 8 buckets and the reactor biological shield plugs. It is then removed from the reactor and placed on a raised stand. Transport shield-flasks for individual buckets are then passed by rail under the unit and the buckets are discharged from the magazine. The reverse procedure is used for the loading of materials into the reactor.

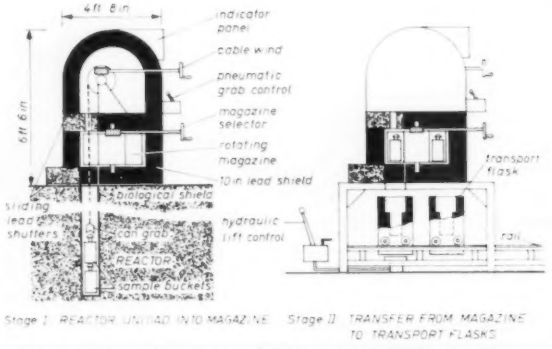
High flux irradiations The equipment designed for the production of high specific activity cobalt-60 is an example of one arrangement used for irradiations in neutron fluxes



1 Magazine selector control 2 Magazine selector mechanisms 3 Load push rod 4 Can load port 5 Isotope can 6 Can arresting gate 7 Can transport passage 8 Irradiation magazines

Honeycomb unit for the DIDO isotopes irradiation machine, for simplicity only three magazines are shown instead of ten (Fig. 3)

of about 10^{14}/cm²s, where special cooling is necessary. It is possible to simplify the apparatus where immersion of the target materials in the D_2O moderator is permissible; this obviates the need for a special cooling circuit with its associated temperature and flow controls.



The unload equipment for BEPO vertical TE/holes (Fig. 4)

The cobalt equipment is for a 2 in dia. vertical hole, and houses 30 metallic disks, 17 mm dia. by 2 mm thick, each sealed and leak tested in a permanent sheath of aluminium. The disks are spaced 2 cm apart with segments of Mg-Zr alloy to form a cylindrical stack; this is sealed in a tight fitting aluminium tube with all the parts being in good thermal contact.

The tube assembly is held in a water jacket formed by the 2-in diameter main outer tube which carries the whole structure. Demineralized water-cooling is used to dissipate the nuclear heating of about one kilowatt. Water flow and leakage trips are provided as well as continuous temperature monitoring.

Medium flux irradiations

Some simple multi-purpose sample racks have been used in fluxes up to about 10^{13}. Loads are arranged to limit the operating temperature without special cooling and heat removal by convection is improved, if necessary, by the use of a helium atmosphere instead of CO_2.

One type of rack consists of a series of standard can holders spaced on a central support shaft. The holders are free to rotate on the shaft to facilitate access to samples with remote handling tongs. The loading and unloading of samples is carried out by withdrawal from the reactor at shut-down, directly into a shielded handling and viewing box. Samples can be changed and transferred into transport containers by a shielded sliding drawer.

Other equipments

A number of facilities of specialized interest are available including: furnace equipment for irradiations in a temperature up to 900°C; low temperature irradiations down to −180°C using liquid nitrogen; irradiation under pressure at up to 2000 lb/in²; fast fission fluxes are obtained in special hollow fuel elements; irradiations with reduced gamma radiation field using installed lead shields; the reactor thermal columns provide conventional facilities for an environment with low fast neutron content.

Acknowledgments

The reactor production or radioisotopes is made possible by the types of equipment described and the work of many colleagues is acknowledged. Much of the information presented is due for publication as part of a Harwell Document introducing the use of reactors to chemists. Publication is by kind permission of the UKAEA.

The new facilities for producing and handling radioisotopes at Saclay have just been completed and will soon be commissioned.

Specialized laboratories for producing radioisotopes

by C. FISHER, Head of the Radio-element Department, CEA*

THE CONTINUOUS RISE in the production of artificial radio-elements by the Atomic Energy Commission has made it necessary to build new facilities. These have been designed to incorporate all the experience acquired on the best methods of containing the materials handled, and reducing the possible consequences of contamination incidents. In particular, there is almost complete separation of the handling cells and the laboratories housing the staff. A description is given of the general layout of the internal fittings, ventilation, and the network of effluent pipes.

France is the second largest European producer of artificial radio-elements after Britain. This production is rising apace with the construction and commissioning of new reactors by the Atomic Energy Commission. For instance, in 1960, the Commission made 9960 deliveries of radioisotopes against 7200 deliveries in 1959. Forty per cent represented deliveries abroad, to some 25 foreign countries, against some 35 per cent in 1959. Deliveries during 1960 comprised, inter alia (1959 figures in brackets):

3600 (—) curies of iridium-192
117 (540) curies of cobalt-60
112 (86) curies of colloidal gold-198
126 (70) curies of iodine-131
55 (30) curies of phosphorus-32

The radio-element division planned to produce in 1960 100,000 curies of cobalt-60 and to start up a pilot plant for the extraction of caesium-137 from solutions of fission products, which will enable several kilocuries of this radioisotope to be recovered.

The implementation of this programme and the steady development of demand for various radioisotopes destined for medical and industrial uses would soon have been slowed down by lack of laboratory space, especially of hot laboratories. It was therefore decided at the beginning of 1959 to build new facilities at Saclay specially designed for the production of radioisotopes. These were completed at the end of 1960 and will be brought into service during 1961.

The French Atomic Energy Commission produces about 110 various artificial radionuclides and over 150 different tracer molecules. When commercial radioisotopes can be obtained from fission products it will be possible to step up production capacity and cut costs accordingly. A semi-industrial plant of this type will shortly be put into production in France.

Statistics for 1957 show that the French industry saved approximately £330,000 by the use of radioisotopes. This figure is much higher now as the number of consignments despatched by the French Atomic Energy Commission have more than doubled over the past three years. The export production goes mainly to the Common Market countries and the USA.

At Saclay there are three cells designed for handling Co-60 sources

1 *The handling cell; designed for handling and packing sources irradiated in reactors*

2 *The second cell stores the sources*

3 *Irradiation cell; the gamma rays are provided by sources from the storage cells*

GENERAL PRINCIPLES

The general principles by which the planning of the new building was guided were based on the experience acquired over a number of years through operations at the high activity laboratory at Saclay. Production equipment there is installed in laboratories, all identical, measuring 10 m × 15 m (32·8 ft × 49·2 ft), connected by a central passage, each having individual ventilation (injected and extracted) as well as liquid effluent lines.

In use, this type of building has shown two main defects, which are as follows:

1. The design of the building does not provide for ordinary laboratories side by side with the hot laboratories

*The installations described in this article were planned and designed by a group of researchers led by Messrs. Duvaux and Junca from the Construction and Installation Division of the Courouble, Laurent, Germond and Raggenbass, from the Radio-element Division.

where ordinary chemical operations or physical measurements can be carried out.

2. As various pieces of equipment are working simultaneously in the same laboratory any incident resulting in contamination brings about a temporary cessation of work in the whole of the laboratory and, consequently, holds up production of several radioisotopes. Incidents of this nature almost invariably happen when loading and unloading operations are in progress and also when maintenance work is being carried out.

Additionally, a number of minor defects have been revealed during operations. For example, the roof height of 3·40 m (11·15 ft) is inadequate to enable handling equipment and remote controlled handling equipment to be employed. Moreover, effluent pipes have been placed in ordinary channels which are difficult to inspect. The consequences of any leakage of radioactive solutions could be serious.

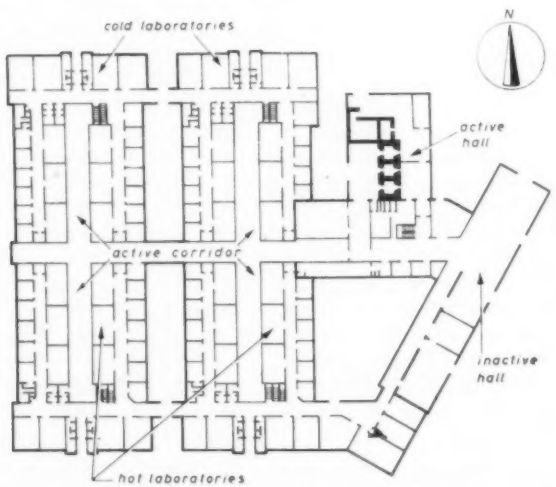
All these different defects have been eliminated by basing the construction of the new buildings on an 'active passage'. This active passage, 5 m (16·4 ft) wide, and 4·20 m (13·8 ft) high, links and serves the laboratories lying each side of it. The laboratories are separated from the passage by means of thin panelling. The boxes in which the radioisotopes are handled are located in the passage; they are fixed to the panelling by means of an air-tight attachment, and, whenever required, are enclosed by shielding on the three sides in the passage, and on the fourth side facing the laboratory.

Each of the active passages is located above a service corridor high enough to allow easy access. The effluent lines run through the service corridor.

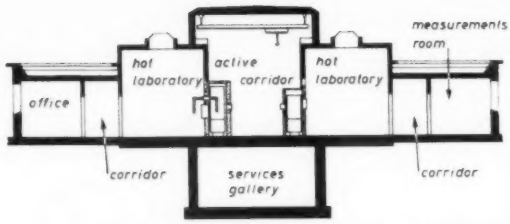
GENERAL DESCRIPTION

The building has a total covered area, including the basement and a first floor covering only part of the ground floor, of 9800 m² (105,486 ft²), representing a working area of 4000 m² (43,056 ft²). Figure 1 shows the plan of the building. The external dimensions are approximately 75 m × 90 m (246 ft × 295 ft).

For main sections corresponding to different processes are shown on the plan of the building.



Ground floor plan of the building (Fig. 1)



Section through the hot laboratories showing the position of the services gallery and active corridor in relation to the hot laboratories (Fig. 2)

Hot laboratories

The facilities through which the central active passage runs, are made up of four sections. Each section has a length of 25 m (82 ft) and comprises laboratories, each 4·5 m × 7 m (14·8 ft × 23 ft), located on both sides of a secondary active passage. Facing them, a number of rooms, each measuring approximately 3 m × 3 m (9·8 ft × 9·8 ft), have been arranged. These can be used either as offices or metrology laboratories. The active passages of each section connect with the central passage, but access to this from the laboratories can only be obtained by first passing through a changing room and a decontamination room. Entry into the passage, normally free, can be barred or restricted in the event of accidental contamination.

Figure 2 shows a section through the hot laboratories. It will be seen from this that the active passage is higher than the laboratories so that handling equipment of the travelling gantry type can be used, as well as to allow room for the ventilation ducts.

In normal operation of the installations, those laboratories which are separated from processing cells are regarded as being in a cold zone, and there is no particular check on access to them. It is, of course, understood that radioactive products are never carried through these laboratories, at any stage of the proceedings, and all loading and unloading of equipment takes place on the hot passage side. In the event of a serious accident, involving the contamination of a laboratory, it is possible temporarily to connect whichever one is involved directly with the active passage, and to bar normal ingress to it. A laboratory contaminated in this way is, consequently, regarded as an integral part of the actual zone until it has been decontaminated. An emergency exit, situated at the end of each active passage, incorporating a decontaminating shower, enables staff to get away in the event of an accident occurring within a passage.

Cold laboratories

The cold laboratories are located at the end of each bay of hot laboratories. There are 4 per section, each 5 m × 6 m (16·4 ft × 19·7 ft). Their equipment is that found in ordinary chemical laboratories. The staff enters and leaves via the cold laboratories, as also does any equipment not destined for the active passage.

Active hall

Certain operations involving intense radiation, such as those with cobalt-60 require very special protection, and the use of cells or caves with thick concrete walls. An active hall has been allocated for the construction of these caves, of which there will be three.

Two caves will have shielding adequate for handling ten

kilocuries of cobalt-60 and are equipped to strip the casing or sheath from the irradiated metal, measure and manipulate the sources and place them in storage. Storage capacity, which is partly buried, has been allowed for 100 kilocuries. The third cave, located alongside the storage well is designed to handle 100 kilocuries of cobalt-60. In it irradiation with intense gamma sources will be carried out to customers' specifications.

The block of three caves divides the hall into two entirely separate zones. The outer zone is the operating zone from which the various processes are controlled. The inner zone is the zone from which loading and unloading operations are performed. This is the classical arrangement with the added advantage that the inner zone of the caves connects with the central live passage and, consequently, access to it is under control. At the same time, the decontamination room of the active passage can be used for these caves.

The hall is equipped with a travelling crane of a lifting capacity of 10 tons, so that heavy loads can be handled.

Clean hall

Packing and despatching operations for radioisotopes call for the use of a warehouse of ample dimensions. For this purpose a clean hall has been provided, having a length of 60 m (196·8 ft) and a width of 11 m (36 ft), half of which has been laid out as a mechanical workshop and glass blowing shop, and the other half as a packaging material store and despatch centre. This hall has been located on the ground floor and access has been arranged so that despatch vehicles can drive into it for collecting packages. A 10-ton lift travelling crane has been installed so that heavy loads can be handled.

Offices

Administrative staff and technical staff offices have been located on the first floor, above the cold laboratories, situated on the south side of the building.

INTERNAL EQUIPMENT

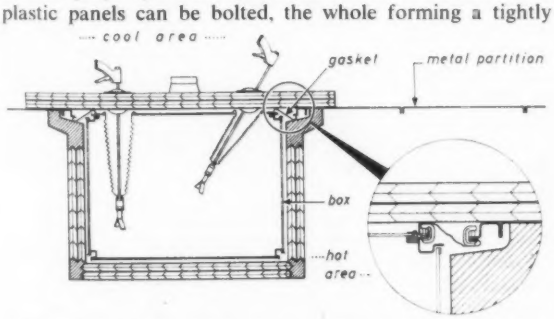
Processing boxes

Internal equipment consists basically of a large number of standard units—glove boxes—in which the chemical separations are carried out.

Figure 3 shows, schematically, how these boxes are fixed to the metal panelling between passage and laboratories.

Two standard sizes exist chosen so that three large or five small boxes can be fitted to the wall of one laboratory. These boxes can be joined by removing lateral walls or by access ports.

Each unit consists of a framework or metal or reinforced polyvinyl chloride channel, on which metal or plastic panels can be bolted, the whole forming a tightly sealed shell. The chemical equipment is mounted inside this box, the forward wall of which is sealed to the passage wall by a flexible joint. Handling tongs and operating levers pass through this forward wall via leak-tight joints or plastic sleeving.



Method mounting a box in the active corridor (Fig. 3)

When shielding is required a second framework is built round the box to support walls made of lead bricks and, if needed, a roof. Again they are built on three sides in the passage and on one in the laboratories.

A negative pressure of 2–5 cm w.g. is maintained in all boxes. They are connected to an extraction tube located in the active passage and serving three laboratories. A primary filter is incorporated in the exit to this tube in each box.

This type of standard box is very suitable for permanent installations used for continuous production. For diversified operations 'junior-caves' have been devised which are a type of shielded glove box. They are designed to take advantage of the division of the new facilities into active and clean zones. They open from the rear and are equipped with remote handling devices designed by the Commission which pass through the shield via air-tight joints.

All these boxes and caves are connected above to all services including air exhaust, water and other fluids and below to the effluent channels.

Ventilation

Only the active passage zone is air-conditioned and maintained at a lower pressure than the rest of the building, which results in considerable saving as compared with conditioning the whole installation. Complete renewal takes place at a rate of 20 times an hour in the active passages. The air exhausted from all passages is passed through a series of filters before escaping through a stack standing some 5 m (16·4 ft) higher than the roof of the buildings.

The air control system covers only a relatively small volume of the building and consequently its cost represents only six per cent of the overall costs.

Liquid effluent

Effluent lines are situated in the service corridor, beneath the processing cells. For radioactive waste the pipes are made of Pyrex glass, and for inactive liquids, of lead. They have been designed to join together in lengths of 1½ m (4·92 ft).

A set of hold-up tanks is located in the service corridor, at the end of each wing of the hot laboratories. Active liquid is collected in two of the tanks; two others are intermediary tanks for monitoring waste liquid believed to be inactive.

The hold-up tanks are arranged to provide easy access and facilitate removal of their contents by tankers.

UTILIZATION

Since this building has only just been completed another year must elapse before experience in its utilization can be gained.

This will be interesting to compare with that acquired in other radioisotope production centres because in these new facilities, containment has been pushed to a very advanced stage and the operators are completely isolated from the active zone, whereas current practice—also in France—is to permit access to all the faces of the boxes and caves in identical conditions.

There is an application
in almost every industry

Uses of radioisotopes and irradiation

by *DAVID IGGULDEN, B.Sc., Technical Editor,* Nuclear Power

THE WIDESPREAD USE of radioactive techniques has been one of the major advantages arising from the discovery and utilization of nuclear power. The interest surrounding this new tool has also led to irradiation, not necessarily from radiosotopes, becoming an important aid to the manufacturer and research worker. Contributions, for example, to research and process control have been made in a wide variety of industries. Greater accuracies are now available in the field of process control, especially that of thickness measurement, while in the research field, radioisotopes provide a unique method for solving problems which would have been impossible or difficult by 'conventional' techniques.

Radioisotopes have three important advantages over other research tools. They do not need power supplies as they are self-contained energy sources; they are unaffected by physical conditions so that their radioactive properties are reproducible; and they are easily detected.

Industrial applications

Industry at present does not take full advantage of the many routine applications of radioisotopes available. The commonest use is in process control. Beta or gamma rays, with suitable detectors, can be used to measure thickness either by penetration or back scatter. As there is no contact the method is useful for continuously monitoring moving material and has now become the standard instrument in the paper making and sheet steel industries. Other allied applications are plastics and coated fabrics. Similar methods can be used in production lines to check the contents of filled packages. This type of application is widespread in the cigarette manufacturing field and has also been used by toothpaste manufacturers. An incidental advantage of the use of radioisotopes in mass production systems is that the associated electronics of the detecting devices can be easily integrated into the system.

Radioisotopes form an integral part of the petroleum industry where they are used for measuring flow through

In this gamma ray machine made by Gamma Rays Ltd, the source is 5 c of irridium-192 and in this application it is mounted on a quadrant and stand with extensible legs for weld examination. The exposure can be made in a very short time by operating the safety catch (Fig. 1)

pipelines, interface markings of pipelines, catalyst mixing and location and research into the mechanism of entrainment in refinery distillation. The success gained here suggests that these methods could be used in many other fields and small amounts of radioactive tracers are being used to measure bulk flow in large industrial plants and also to check on the effectiveness of recycling processes.

There are also applications to wear problems in general; the best known are piston ring and cylinder wear, and tyre wear. Work in the machine tool industry is aimed at improving the efficiency of machine tools by studying the distribution of wear debris.

Other straightforward applications include the routine inspection of pipes for leaks. Radioactive liquid is pumped through the pipe which is then flushed. A 'go-devil' is then passed through the pipe and is able to detect and record any of the radioactivity which may have seeped into the surrounding ground.

Radiographs obtained with high energy gamma sources are in widespread use. Their advantage over X-ray machines is that as the sources are small, they can be used in positions inaccessible to X-ray machines. As they are independent of electrical and water supplies they are well suited for field use and for awkwardly shaped materials (Fig. 1). A common application in the weaving industry is shown in Fig. 2.

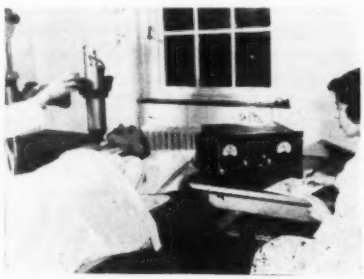
Medical uses

The majority of isotopes produced go to the medical field, where they

This static eliminator being used on a weaving machine has two uses. Fibres become electrified when passing through the loom. This static electricity is a fire risk and also attracts unwanted dust. Small beta sources are used to ionize the surrounding air and thus remove the electric charge (Fig. 2)

have diagnostic, therapeutic and research applications. The use of intense gamma ray sources, such as cobalt-60 and caesium-137, for treating malignant growths is well known. Other clinical uses, also involving irradiation of growths, offer on-the-spot treatment. Suitable elements can be taken up by the areas requiring treatment which can then be irradiated from within.

Application of isotope techniques has enabled a substantial contribution to be made to the knowledge of basic processes within the body and has allowed simple mathematical concepts to be applied to the dynamic state of body constituents. The sensitivity of the detecting devices used has meant that accuracy of measurement of minute amounts of substances has been increased by several orders of magnitude. Their value has been particularly felt in the study of metabolic processes. Even when non-radioactive sister isotopes do not form body compounds, it is possible to use them as labels on compounds of interest as the extremely small amounts required do not have any appreciable chemical effect.



A scintillation counter is used to plot accurately the area of the thyroid which has selectively taken up radioactive iodine (Fig. 3)

The well-known application of I-131 or 132 to the treatment and diagnosis of thyroid conditions has demonstrated the presence of previously undiscovered thyroid hormones (Fig. 3). Radioactive iron and sodium have been instrumental in the discovery of other new hormones. Another promising application is the use of P-32 and latterly of Bi-206 for tumour localization. Phosphorus metabolism takes place at a different rate in tumour cells and needle counters can be used to plot the area accurately.

Bulk irradiation

With the availability of large-scale gamma emitters in sight (by 1965 it is expected that 10^7 c/a of Cs-137 will be available from fission product separation), industry is faced with the problem of whether to use these new methods or machine-produced irradiation. The question will in all probability become one of economics. It is expected that electron accelerators will become more powerful and simpler and the main advantage that they offer is that they can be turned off when they are not being used.

Bulk irradiation is mainly used (*a*) when it is desired to change the properties of a material by altering its molecular composition and (*b*) when some unwanted property is destroyed or inactivated without affecting the body as a whole. In the first class, gamma radiation is able to induce reactions at lower temperatures and pressures and, in some cases, without the need of a catalyst. In this field the common applications are polymerization and cross-linking of polymers, and vulcanization of rubber. In some instances, the results are novel products unobtainable by other means, or the irradiation results in improvement of physical properties. In the second class, a light dose of gamma irradiation may be used to inhibit sprouting potatoes and onions. Irradiation can be used to reduce bacterial populations and so is useful for increasing storage life of foods. In these cases problems connected with unpleasant 'off-odours' are being overcome. Bulk irradiation is also being used on a large scale for the sterilization of sutures and other surgical appliances. Antibiotics, which would be aversely affected by heat treatments, can be successfully sterilized in this way.

During the past year, two bulk irradiation plants have been opened, one in the UK at Wantage and the other in Australia. The latter will be used for sterilizing goat hair against the anthrax bacillus. A pilot plant irradiation facility has also recently been opened to demonstrate to manufacturers the possibilities of machine produced irradiation.

Agricultural uses

It has been said that the outstanding future contribution of radioisotopes may well be in the field of agriculture. One half of the world's population at present goes hungry and world population is rising. Radioisotopes can aid in the production of new and effective fertilizers by their use in growth and nutrition studies. Irradiation increases the natural mutation rate and provides new and improved characteristics for the plant breeder. Strains of oats which are especially resistant to disease and wheats with short straw lengths have been developed by these means. It has already been successful in the fight against the screwworm fly and similar techniques are being used to control other insect pests which destroy animals and crops.

A research tool

Research applications are numerous and development work is naturally carried out into all the types of applications mentioned. The main uses have been in the field of analytical chemistry; complex mixtures can be analysed by means of the characteristic radiations given off when the material is activated; this method is

This midget generator fuelled with polonium-210 was successfully operated in a vacuum and down to −100°C. The system, designated SNAP-3, is produced by The Martin Company (Fig. 4)

far more sensitive than chemical analytical techniques. The technique eliminates the need for reagent blank corrections and has high specificity. In some cases direct readings of impurities are possible. The technique — radioactivation analysis — is now an established tool and a symposium was held under the auspices of the IAEA.

Another well-known research application is radioactive dating. Measurements of the C-14 content of archaeological specimens enables them to be dated to within about 100 years. The C-14 with a half life of 5500 years is present in equilibrium amounts in the specimens and is assumed to decay when organic material contained in a plant or animal is incorporated into the specimen. The C-14 is produced by cosmic radiation via N-14.

Isotope power

One of the more exotic uses proposed for isotopes is for powering satellites and space probes. Isotope sources such as polonium-210 and cerium-144 are used to generate heat in the walls of a container in which are situated thermoelectric elements to produce electricity directly (Fig. 4). The device offers advantages over the solar cell as it is not affected by micrometeorites, will operate in the shadow of the sun and has no moving parts.

A large industrial demand has not materialized despite the promise of substantial savings

Industry neglects radioisotopes

by SIDNEY HOLLANDS, B.Com., News Editor, Nuclear Power

MORE THAN £1000 an hour could be saved by British industry if it applied, in full, known radioactive techniques. This is in addition to present savings estimated at £3·5 million annually now achieved by firms using isotopes. Within 25 years time, provided there is general use by industry, the savings could rise to £70 million yearly. Furthermore, these figures are based on present known applications in a field which is comparatively undeveloped and one in which the list of potential developments and savings seems limitless.

Yet, on the whole, there has been a disappointingly quiet response from industry. The Atomic Energy Authority's sales in 1959–60 were valued at £1·1 million of which 60% went to overseas markets. Of the 35,000 deliveries made during that year, 50% went to medical users and 15% (25% of the total value) went to industry.

Various theories have been put forward for the slow growth of the industrial market. One is that wider use has been held back by innate conservatism, prejudice and ignorance both of the applications of radioisotopes and of the legal and insurance problems involved. It was partly to overcome this difficulty of making contact with industry that the AEA opened its Isotope Information Bureau last year. The Authority also has an Industrial Liaison Group whose staff visit industrial areas to demonstrate the potentialities of radioisotope applications in commercial processes.

Legal aspects

On the legal and insurance side, there is no reason for industrial firms to fear hold-ups because of 'red-tape'. There is, for instance, no legislation at present making it compulsory for factories to inform the authorities of their intention to use radioisotopes. This position will change when the Factory (Ionizing Radiations) Special Regulations become law; it will then be compulsory to give one month's notice of the intention to install sealed sources or X-ray machines. Also in preparation is a draft code governing the use and installation of unsealed sources which will take much the same lines. In the meantime, however, the Ministry of Labour ask firms to notify their local district inspector of factories of their intention to use isotopes.

The present position for insurance is broadly that no special provision is made where low-level radiation sources are used. No change is expected in this attitude though the field of atomic energy insurance is being reviewed in a report under preparation by an advanced study group of the Insurance Institute of London. For megacurie sources and large irradiation facilities, individual provision is made by insurance companies.

> Increased interest is being shown in the use of radioisotopes, with enquiries at the AEA's Isotope Information Bureau running at the rate of about 90 a week. However, much needs to be done before savings estimated at £14 million a year can be achieved by British industry. The present figure is nearer £4 million with the AEA business in isotopes running at about £1·1 million

Economic advantages

A further theory advanced is that the economic advantage of radioisotope use is difficult to estimate and, as such, has given rise to reports that the benefits have been below expectations. This theory has some basis when linked to uses such as research and investigation and when these materials are used for 'once-only' applications such as the search for pipeline blockages—uses which do inhibit the growth of the market. But when considered against the main industrial uses of radioisotopes — thickness gauging, industrial radiography and research and process control—this theory fails.

Though no recent detailed cost figures have been produced in the UK on the savings these achieve—the AEA estimate is £3·5 million a year—the US National Industrial Conference Board in a report in November 1959 produced a table showing the estimated annual savings of 595 companies. The total was given as just under $40 million with savings in the petroleum industry given as nearly $12 million, in the chemical industry as $4·5 million and in paper and allied products as $2·8 million. The Board also pointed out that the total economic value of radioisotopes in industry 'cannot be accurately assessed. A product which is materially improved may not only return a higher profit to the maker but may contribute lower costs and higher values to those who use it or resell it'.

In the meantime, new applications are being found for isotopes for the industrial potential has hardly been tapped. One possible use being discussed is in the field of automation. Many plants may well become completely automated through the development of ultra-sensitive radiation detection instruments for use with very low levels of radioactive materials. There is also the possibility of further large-scale applications of radioactive techniques for sterilization purposes such as that used in the plant built in Australia by the AEA for sterilizing goat hair for a carpet manufacturer.

But the basic problem still remains —that of getting a more widespread acceptance by industry of this new technique. And industry itself must make the major effort towards finding a solution. As Sir Hugh Beaver, then the acting president of the Federation of British Industries, said when the AEA Isotope Information Bureau was opened '. . . here is a weapon which can be used probably in every sort of production creation and activity in this country . . . If we cannot show ourselves more competitive than the rest of the world, more able to use new methods and techniques, then our way of life and our standards of living and our supremacy in the industrial world is challenged and will go'.

Increase in pressure vessel plate thickness has made weld inspection difficult. Current techniques are evaluated with special reference to linear accelerators

Electron accelerators for site radiography

by R. F. HANSTOCK, Ph.D., F.Inst.P., UKAEA, Development and Engineering Group, R. & D. Branch Laboratories, Culcheth

GAS COOLED, graphite moderated reactors of the Calder Hall type and of more advanced types planned to operate at higher temperatures require large pressure vessels fabricated from steel plate by welding. The dimensions of some of the pressure vessels now under, or planned for, construction are given in Table 1, one dimension indicating that the vessel is spherical, two dimensions that it is cylindrical. Whilst the first civil power stations have pressure vessels built of three inch plate the thickness for the later stations has increased towards 4½ in. Typically, the construction of each pressure vessel of a nuclear power station involves about 2500 ft of plate-to-plate butt welding.

Detailed inspection of the pressure vessels during their operational life is practically impossible, although certain arrangements may be made to assess indirectly deterioration in properties of the steel. Examination of specimens subjected to fast neutrons shows that the most important effect on the steel is an increase in the tendency to brittle fracture, a mode of failure that is dependent on the presence of a notch or small crack for its initiation.

However good the technique of inspection may be, it is not possible to discriminate between defects certain to cause failure and those which will not. Thus it is of first importance to establish welding techniques which give high quality welds. Defects revealed by inspection after welding by these approved techniques are then scrutinized by the inspecting authority responsible for deciding whether the welds are acceptable. This decision requires considerable experience to avoid, on the one hand, the vessel going into service with dangerously defective welds, and on the other hand, unnecessary welding repairs. The main information upon which to base this decision is provided by the radiographs of the welds, and the technique of radiography should be that best able to resolve defects.

For the inspection of butt welds in pressure vessels up to three inches in thickness, radiography with fine grain film using equipment operating at voltages up to 400 kV has been widely used and an acceptable standard of inspection has been achieved. However, it is not possible to maintain this standard with 400 kV equipment when the plate thickness exceeds three inches.

Radiography of butt welds greater than 3 in thick

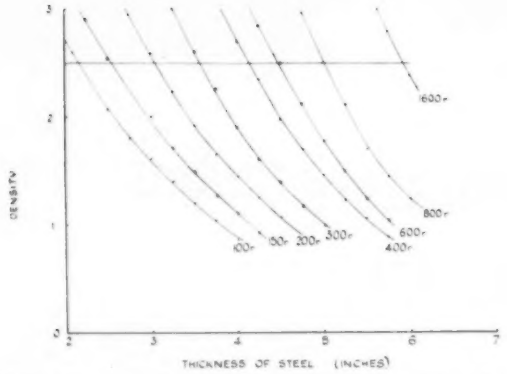
The future for inspection of pressure vessels fabricated in plate thicker than 3 in depends on either the adoption of an entirely different method of inspection or on the use of technically more suitable X-ray or gamma ray equipment. The use of such equipment on the site of construction presents problems which have yet to be experienced fully. Although future development of ultrasonic methods may provide another method of inspecting welds in thick plate, wide experience of radiography favours the trial of radiographic sources providing high energy radiations, emitted either by radioactive isotopes or by targets bombarded with electrons of MeV energies.

Cobalt-60 sources

Several cobalt-60 sources (half life 5·25 a) of kilocurie strength and specific activities of 30–40 c/g are being used by consortia constructing reactor pressure vessels. These sources emit gamma rays of 1·17 and 1·33 MeV energies and typically present emitting areas of 1–2 cm diameter. When set up to give limits of geometrical unsharpness comparable to the standard normally applying in radiography of 3-in plate with 400 kV equipment, exposure times of 1–2 h are required with fine grain films for radiography of 4-in plate. With these sources radiography of 4–4½ in plate is feasible to a standard not substantially different from that attained on 3-in plate using conventional equipment. Thus it is in comparison with cobalt-60 that high voltage X-ray sources must be judged. The container for a kilocurie cobalt source weighs about 3 tons and is 2–3 ft in diameter and 3–4 ft long. When an exposure is being made, the source is moved by remote control into a position within the container from which a cone of radiation can emerge. At the end of the timed exposure or in the event of a power failure, the source automatically returns to the safe position. The container and exposure mechanism is robust but not immune from damage. For site use, handling equipment is required to

TABLE 1 *Dimensions of some reactor pressure vessels*

LOCATION	DIMENSIONS, ft	PLATE THICKNESS, in
Calder Hall	37 dia.	2
Chapelcross	70 high	
Hunterston	70	2⅞, 3
Berkeley	50 dia.	3
	80 high	
Bradwell	67	3, 4
Hinkley Point	67	3
Trawsfynydd	61	3½
Dungeness	62½	4, 4½
Tokai-Mura, Japan	60	3 5/32, 3⅝
Latina, Italy	66	3 7/16, 4⅛
Windscale, AGR	21 dia.	3, 4½
	60 high	



Film densities for 2½–6 in steel step wedge, integrated dose at one metre (Fig. 1)

bring the container into position and to steady it during exposure. The provision of extra radiation shielding is a problem which is common to both the use of the multi-curie cobalt-60 source and other equipment producing X-rays of comparable energies.

X-ray sources of MeV energies

There are four types of machines for accelerating electrons to MeV energies and, with the provision of a target for bombardment, they serve as X-ray sources. These machines are the resonance transformer, the Van de Graaff generator, the linear accelerator and the betatron. A comparison of the dimensions and weights of the various X-ray generators based on these four types has been given by Halmshaw and Pollitt (*1*). In all cases the unit emitting X-rays, i.e. the part of the machine that has to be brought into position to radiograph a weld is heavy and bulky, the smallest unit weighing about 1 ton and having approximate dimensions 3 ft × 3 ft × 2½ ft.

Resonance transformer and Van de Graaff machines

In the X-ray generators based on the resonance transformer and the Van de Graaff generator the electrons are accelerated along a multi-section X-ray tube consisting of an evacuated glass tube containing electrodes in sequence at increasingly high potential so that the maximum voltage of the generator is applied over the tube length. The source of high voltage, generally 1–2 MV, is the secondary of the resonance transformer or, in the Van de Graaff machine, a fast-moving insulating belt which conveys electrostatic charge to the cathode of the X-ray tube. The target at the other end of the tube is bombarded by the accelerated electrons and transmits the X-rays that are produced. The tube is enclosed in a tank containing gas at high pressure to provide insulation against the total voltage applied. These machines, operating up to 2 MV, have already been used for radiography but at 2 MV output they are large and heavy and their X-ray output is not very much greater than that of kilocurie cobalt-60 sources.

Linear accelerator and betatron

The acceleration of electrons by potential differences greater than 2 MV introduces difficulties in providing insulation. In the travelling wave linear accelerator and the betatron these difficulties are avoided.

Proposals to use linear accelerators for industrial radiography were made by C. W. Miller (*2*) and the use of a non-mobile unit generating 5 MV X-rays is reported by Halmshaw (*3*). In the linear accelerator, electrons are injected into a wave guide from an electron gun operating at about 50 kV. A radio frequency wave, produced by a magnetron, travels along the wave guide which is designed to increase the wave velocity so that the electrons accelerate in passing along the guide. Before reaching the target at the end of the wave guide they gain energy of several MeV from the radio frequency wave which is thereby attenuated. The magnetron energizing the linear accelerator is pulse operated by a modulator, a unit which may be located separately from the accelerator. A typical linear accelerator operating at about 5 MeV has a wave guide one metre long and this, together with the shielding round the target and the pumps required to evacuate the wave guide, determines the dimensions and weight of the radiographic unit. A very high output of X-rays (about 500 r/min at 1 m) is obtained from a small focal spot.

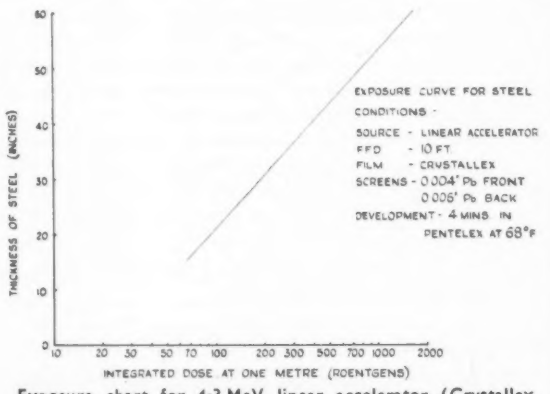
Betatrons give a reasonable X-ray output when energizing electrons to 15–30 MeV.

In the betatron, electrons accelerated through about 50 kV are injected to travel in a circular orbit in an evacuated toroidal enclosure or 'doughnut' of glass or ceramic. The circular orbit is maintained by a magnetic field directed perpendicularly to the plane of the orbit and acceleration is produced by increasing the strength of this field. The betatron may be considered as a transformer in which the electron orbit forms the secondary circuit. The electrons are injected as the field due to the primary current is rising from zero, circulating many times and gaining energy as the alternating field rises to its maximum during the first quarter-cycle. They are then deflected out of orbit to strike the target and produce X-rays. The typical output of X-rays is about one-tenth of the output from a 5 MeV linear accelerator.

Suitability of high energy X-ray machines

Although all the high energy machines that have been described are suitable for radiography of steel of the thicknesses at present contemplated for the construction of nuclear pressure vessels, only Co-60 sources have been used in this country on nuclear power station sites.

Two years ago Culcheth Laboratories of UKAEA reviewed the desirability of introducing high energy machines for site radiography to reduce the exposure times required for radiography with cobalt-60 and to meet the possibility that in future reactors, pressure vessel thickness might



Exposure chart for 4·3 MeV linear accelerator (Crystallex film) (Fig. 2)

increase to exceed the inspection capabilities of the 1·17–1·33 MeV radiations of cobalt-60.

The resonance transformer and Van de Graaff machines do not appear to offer any marked advantages over cobalt-60 sources of high specific activity.

An 18 MeV model betatron, available as a mobile unit (4), is able to radiograph the thickest plates that are ever likely to be used. However, radiation of this energy may introduce more inherent film unsharpness than radiation of lower energy but adequate penetrating power. Although inherent unsharpness can be compensated by a projection technique which is practical with the betatron because of its small focal spot it is considered that the modest output of this machine would result in a relatively low rate of radiography per foot run of weld, particularly if a projection magnification technique is necessary.

The penetrating power of X-rays from the 4–5 MeV linear accelerators is sufficient for radiography of pressure vessels of thicknesses not likely to be exceeded in the future. The output of these machines is attractively high, i.e. ten times that of the betatron and the effective target is small. Although rather heavy and bulky because of the pumping gear required for continuous evacuation, linear accelerators contain no fragile component that is expensive or difficult to replace.

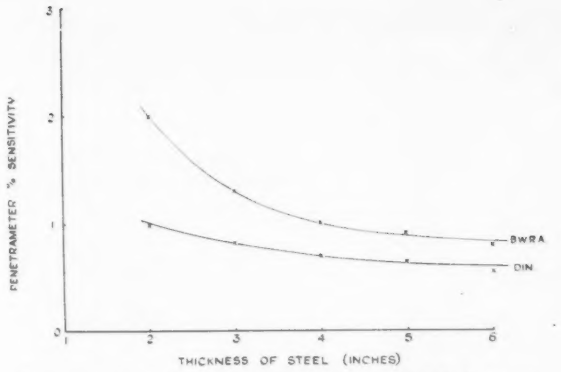
4·3 MeV linear accelerator for site radiography

The UKAEA initiated design studies of a linear accelerator for site use and, subsequently under a contract with the Authority, Mullard Equipment Ltd. developed and constructed a 4·3 MeV accelerator. This has now been delivered to the CEGB Trawsfynydd site to radiograph butt welds in the 3½-in plate of the reactor pressure vessels of the power station being built there by Atomic Power Constructions Ltd.* This first use of a linear accelerator by site contractors will, it is hoped, provide an assessment of the serviceability of the equipment and resolve the problems of handling and radiation shielding that may arise during its use.

Preliminary off-site tests of plate welds of 3–4½ in have shown that no marked improvement is to be expected in the resolution of defects shown in radiographs taken by the linear accelerator, as compared with those taken by a multicurie cobalt-60 source using the best radiographic techniques for these thicknesses of steel. On the 3½-in plate of the Trawsfynydd pressure vessels the main advantages of the linear accelerator should accrue from its high output which, besides shortening exposure times, will allow considerable freedom to choose operating distances that are most convenient for the site conditions. The technical superiority over the multicurie cobalt-60 source should become more apparent when the linear accelerator is used to examine pressure vessels fabricated in thicker plate.

At the front of the head is a radiation shield surrounding and extending beyond the target and carrying rotatable field-limiting shutters. The shielding is such that at 1 m to the side of the target the intensity of radiation falls to 0·04% of the intensity in the radiation beam at 1 m in front of the target. The X-ray field at 1 m is 30 cm dia., the intensity at the periphery being about ⅔ of the intensity at the centre of the field. An optical projector is mounted on the shield to direct a light beam through the shutters on to the plate being examined, thus defining the area

*The accelerator is described on p. 90 of this issue.



Penetrameter sensitivities, 2–6 in steel, for 4·3 MeV linear accelerator using fine grain film (Fig. 3)

irradiated by the X-ray beam. Within the shield and in the radiation beam are the ion chambers which measure the X-ray output. The X-ray head is 8 ft 9 in long by 4 ft 9 in wide and 5 ft high, and weighs 2 tons.

The control cabin contains the modulator and controls, the dose rate and integrated dose meters, and the Castell safety interlocks.

Proving trials indicated a maximum output of not less than 600 r/min at one metre. Radiographs of a steel step wedge varying in thickness from 2½–6 in gave the density plots shown in Fig. 1 for several exposures measured as rontgens at one metre by the integrated dose meter. The film to focus distance in this test was 10 ft and the film Kodak Crystallex with 0·005 in front and 0·006 in back lead screens. The average half value layer calculated from the 2·5 density intercepts in Fig. 1 is 0·95 in of steel. Figure 2 shows an exposure chart derived for Crystallex film to density 2·5 with an F.F.D. of 10 ft. For a nominal output of 500 r/min at 1 m the exposure time to a density of 2·5 for 6 in of steel at 10 ft F.F.D. is approximately 3½ min on Crystallex film.

Penetrameter sensitivities for fine grain films and steel thicknesses within the range 2–6 in are shown in Figure 3 for D.I.N. and B.W.R.A. penetrameters.

Conclusions

The future of radiographic inspection of butt welds in nuclear pressure vessels built of plate thicker than 3 in depends on the use of high energy radiations either from cobalt-60 or from special X-ray machines. Of the latter a 4·3 MeV linear accelerator and an 18 MeV betatron are available in forms suitable for site trial. The linear accelerator although less compact than the betatron has an output 10 times as great as the betatron and the cobalt sources at present in use. The linear accelerator allows short exposures and considerable freedom to choose F.F.D's that are convenient for site conditions.

Acknowledgments

During the course of design studies and the development of the prototype linear accelerator the author had the benefit of discussion with members of the staff of Mullard Research Laboratories, ARDE, AEI (Manchester), CEGB, APC Ltd, Babcock & Wilcox Ltd, and with colleages in the UKAEA, and gratefully acknowledges the assistance of those concerned in this work.

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A wide range of existing facilities and some new concepts were presented to delegates from many countries

Eighth Conference on Hot Laboratories and Equipment

by E. EDMONDS, B.Sc. (Hons. Met.), High Activity Building Manager, DERE

A RECORD NUMBER of 135 abstracts was submitted for consideration by the Programme Committee and 52 of these were finally accepted and are published in full in the Proceedings of the conference (TID7599). Forty of the papers were presented at the conference which consisted of six sessions. Whilst most of the papers were from the USA there were contributions from the UK, France, Germany, Belgium and Italy.

Hot laboratory facilities and hot cells

The first two sessions dealt with Hot Laboratory Facilities and Hot Cells; the range of facilities described was wide indeed as evidenced by the Site 401 Disassembly Facility (*3*) at the University of California Radiation Laboratories on the one hand and the alpha beta gamma metallurgy cell at Dounreay (*5*) on the other.

In the former, remote adjustment, component replacement and complete disassembly of a whole reactor system (Tory II) is projected. In the latter, small alpha gamma active specimens are subjected to delicate physical and mechanical testing in an inert atmosphere.

A new and ambitious approach to the problems of working with highly radioactive materials was described in the paper 'Hot-area concept for radiation test facilities' (*2*). Instead of the conventional hot cell design in which cell size is kept to a minimum, a large shielded area 60 ft by 100 ft is used and manipulation is by means of a robot mobile remote handler equipped with two mechanical arms and two television camera eyes (Fig. 1). A robot radio-controlled tug and robot fork truck are also used. The cost of the robot mobile remote handler was about £30,000 and since at least two such robots would be required to guard against breakdown as well as to ensure fuller utilization of so large a shielded area, the capital costs of such a facility must be large. However, advantages in flexibility, available area, transfer operations, ventilation and safety are claimed in addition to economies in both construction and operational costs. Thus, despite the difficulties inherent in the development of this concept, it is by this kind of effort that major advances in high activity handling methods can become practical propositions. Similar ideas are receiving serious consideration elsewhere. In the design of the Argonne Chemistry Hot Laboratory, although the initial operation will utilize immediately available manipulators, one of the design criteria was that it should be such as to allow the use of robots later (*10*).

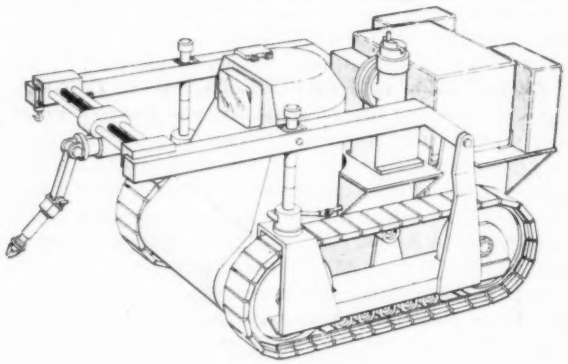
The Eighth Conference on Hot Laboratories and Equipment was held at San Francisco, California, in December. It was the first in the series to be organized by the recently formed Hot Laboratory Division of the American Nuclear Society. Previous conferences were sponsored by the USAEC and the US National Laboratories in 1951, 1952 and 1954, the USAEC and ANS in 1955 and the ASME and AIChE in 1957 and 1958.

A further feature which has not been exploited in previous hot cells is the two or more storey type of structure. This system with a two storey complex is described in the paper on the Argonne Chemistry Hot Laboratory. The hot cell system of the Belgian high flux materials and engineering test reactor (*9*) has a unique vertical stacked arrangement with operations on some seven floors. This arrangement was dictated more by the requirements than the inherent advantages of a stacked hot cell.

In contrast to the majority of papers, one from the Agricultural and Mechanical College of Texas (*11*) described a high level gamma irradiation facility with three modes of operation designed to provide dose rates from 1 to greater than 10^5 r/h. The first consists of a semi-circular field with a radius of 150 ft to provide chronic irradiation to plants and animals stationed in the field. The second allows samples to be placed in the intense irradiation field in the centre of the source while the third permits larger samples to be placed by means of a cart in a tunnel located within the facility shield and provides access to dose rates from 65 to 5000 r/h.

Manipulators and viewing

The third session of the conference was devoted to General Purpose Manipulators and Viewing. The first paper described a small mobile manipulator built at a cost of about £3000 for research on high energy solid rocket propellants where remote operation is necessitated by explosion rather than radiation hazards (*19*) The operation of the manipulator was demon-



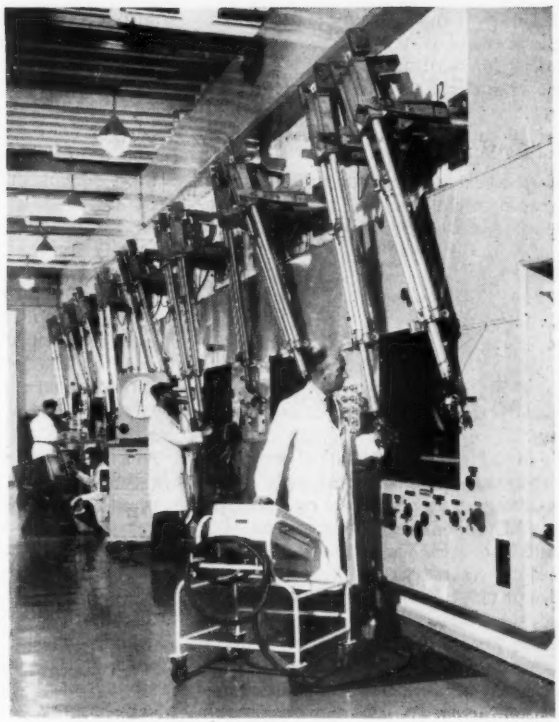
The mobile remote handler (see ref. 2) (Fig. 1)

strated very successfully by a colour cine film with a dramatic ending when the 'robot' unplugged the camera. A second mobile manipulator using a radio controlled base was next discussed. With this, trailing leads are eliminated and the manipulator power is connected after the base has positioned it in the cell where it is to be used. The cost of the unit was given as about £4000.

Another paper describes a radiation stable heavy duty electromechanical manipulator in which radiation effects are minimized first by careful choice of materials and secondly by locating all motors, except the bridge drive motor, in the carriage at bridge height (*20*). This means that they are in a radiation field lower by a factor of 10–100, they can be shielded with up to 4 in of lead with little expense to the power requirements of the manipulator and also remote maintenance is possible by the replacement of units.

A final paper on manipulators described a highly complex electrohydraulic bilateral servo manipulator in which the operator wears a harness over his hands and arms (*22*). The normal arm, hand and finger motions actuate electrohydraulic transducers so transmitting control signals to the slave and reflecting slave forces to the operator. Whilst each arm is capable of lifting 75 lb in its weakest position, complicated movements such as finger and thumb bend and curl are also provided.

The final paper in this session described the remote viewing techniques in use at the Atomics International Experimental Test Facility (*23*). Because of the anticipated high neutron flux to be emitted by reactors running in these cells, windowless viewing is required. To meet this requirement, considerable development of closed circuit television equipment has been carried out. In the cell primary viewing is by means of a traversing television system. In operation, two cameras mounted on adjacent walls are traversed to that point at which each camera is aligned on the object being observed. The right angle views obtained are displayed on adjacent monitors in the control console and it is claimed that this rectilinear display has been found to be ideal for use in directing a rectilinear manipulator. The system requires a television operator controlling the cameras and associated equipment in unison with the manipulator operator and would seem to impose the need for very rigid operator discipline. In addition to the traversing system, a miniature vidicon camera measuring only 2·6 in square by 7½ in long exclusive of the lens has been developed. This has been used attached to the forearm of the rectilinear manipulator and also attached to a mechanism which penetrates the roof of the cell through a vertical stepped port. No operational experience of camera lens browning due to irradiation, or the development of radiation resistant stabilized glass lenses was available.



The high activity examination building at Dounreay (Fig. 2)

Operation of hot facilities

The experience gained by the managers of hot facilities was dealt with in the fourth session and for this discussion, the two papers from AERE given in session one are considered under this heading (*4, 7*). Since the ultimate goal of all hot cell facilities and equipment is to operate successfully on active materials, this was perhaps the most interesting part of the conference. Together with numerous lines of parallel development in operating techniques and procedures, some important variations between different laboratories became evident.

The first paper described the operation of a plutonium hot cell at the Los Alamos Scientific Laboratory (*25*) and it is valuable to compare the techniques used with those in use or projected elsewhere. The basic principle is to set up the experimental apparatus in a hermetically sealed box. After installation and testing of the equipment, a trial run is performed on a 'mock up' stand. When this is satisfactory the box is transferred into the shielded cell, services are connected up and the experiment conducted on the active material. This coincides in many ways with the practice at AERE Harwell. Here, stainless steel boxes are used instead of perspex, the shielding is lead instead of concrete, manipulation is by ball-tongs in place of master slave manipulators and posting utilizes high frequency welded plastic bags as opposed to the sealed can technique. General break down, metallographic and other methods of testing such as gas samplings are very similar. The manipulator gaitering system described in the plutonium hot cell paper suffers from the disadvantage that although manipulators may be changed with some difficulty by gradual withdrawal as the box is remotely moved through the rear door of the cell, no remote change of gaiters is possible. Despite the difficulties the cell has operated on irradiated plutonium reactor fuel specimens of up to 200 to 300 MeV curie activity levels for one year. In the paper in Session I on operations in the high activity handling building at Harwell (*7*) and that in Session IV on the inspection of irradiated materials at Dounreay (*29*), operational experience in two very similar types of British facilities were described. Perhaps the greatest interest was displayed in the hot radiography methods developed in the UK but not employed in any of the other facilities described at the conference. Whilst the gamma scanning technique used in many US hot

facilities is undoubtedly a useful tool, particularly in the selection of specimens for burn up analysis, it can only be considered to supplement and not replace radiography. It is of the utmost value to be able to non-destructively check the integrity of a rig after a period of irradiation. By suitable radiographic techniques this can be accomplished and the rig returned to the reactor for irradiation to a higher burn up.

The UK methods of manipulator gaitering utilizing an alpha wrist seal developed at Harwell appear to offer some advantages particularly with regard to the restriction of contamination spread during manipulator changing.

In a frank appraisal of both the advantages and disadvantages which had come to light in the operation of the Components Development hot cells at Atomics International, the author raised some very pertinent points (*28*). In a plea to hot cell designers it was suggested that operating areas were inevitably required to house large quantities of control equipment, and to facilitate working should be as large as possible. Considerable shielded storage space for contaminated equipment not in continuous use is necessary. The 'mock up' area for proving equipment before installation in cell, and the manipulator maintenance area had both proved to be invaluable. General waste handling and liquid waste disposal deserve the most careful consideration in hot cell design if operation is to be efficient. A most difficult problem, which can only be solved as more data is collected, is that of cost accounting. In a hot facility some 20 or more jobs may be in hand at any one time and since procedures and requirements constantly vary as tests proceed, accurate estimation of costs is most complex and time consuming. At Atomics International a mechanical accounting system is being considered to locate weak spots in operational methods and to accumulate data for future estimating. As a result of several years operating experience the author of the paper on the Battelle Memorial Institute Hot cell facility presented some interesting information on breakdown of time spent between various operations such as waste handling, testing, decontamination etc. and it is apparent that accounting is likely to assume an increasing importance as the hot cell business develops towards commercial competition (*27*). Since decontamination always occupies large amounts of operational time the paper on the use of solvent soluble films in decontamination suggests notable possible savings. Experience over a 3 year period has proved that equipment coated with Flo-master ink before contamination can be decontaminated from greater than 20 r/h to 20 mr/h by removing the film with a suitable organic solvent.

Specialized equipment

Here, the description of the remote assembly of reprocessed fuel subassemblies for the Experimental Breeder Reactor No. II at Argonne National Laboratories illustrated the complex type of operation possible by remote control. Equipment for the remote construction of reactor core sub assemblies in a radiation field of 10^5 r/h and with a fission product heat output of 8 W from each of the 92 pins in the subassembly was illustrated.

Finally, an excellent colour cine film showed modification and repair of the Homogeneous Reactor Experiment — 2 core vessel (*43*). Working under conditions of extreme physical limitation and radiation hazard, the core vessel was inspected, measured, cleaned and two holes in it repaired. Some remarkable viewing, manipulation and machining equipment was developed for the purpose.

PAPERS PRESENTED

Hot laboratory facilities and hot cells

1. A Versatile University Laboratory for Studies on the Basic Chemistry of Alpha Emitters—F. Weigel (UMUN)
2. Hot Area Concept for Radiation Test Facilities—J. L. Colp (SC)
3. The Design and Construction of the Site 401 Disassembly Facility—W. R. Moran (UCRL-L)
4. Remote Handling of Irradiated Alpha Active Materials in the Met. Division, AERE—J. H. Venables (AERE)
5. An Alpha Beta Gamma Metallurgy Cell at Dounreay—S. A. Cottrell, J. E. Manson (DERE)
6. A Highly Active Pilot Plant for Processing Experimental Fast Reactor Fuels—K. Hartley, T. W. Allen (DERE)
7. Operations in the High Activity Handling Building, B.459—J. E. Brown, A. B. Ritchie (AERE)
8. Hot Facilities of CNRN—A. Cacciari, *et al.* (CNRN)
9. The Hot Cell System of the Belgian High Flux Materials and Engineering Test Reactor BR2 — J. P. Valentin (CEN-BELGIUM)
10. Argonne Chemistry Hot Laboratory—C. H. Younquist *et al.* (ANL)
11. A Gamma Irradiation Facility — J. R. Randall, J. A. Reuscher (TEX A-M)
12. Radioisotope Production Building — C. Fisher, R. Henry, J. M. Courouble (CEA-FRANCE)
13. Plant for Separation of Polonium-210 from Bismuth—R. Henry, J. Destoches (CEA-FRANCE)
14. New Hot Cells and Hot Laboratories—Y. Duvaux *et al.* (CEA-FRANCE)
15. *Design and Construction of the Republic Aviation Hot Laboratory — R. L. Zimmerman and T. R. Cuerou (REP)
16. *The General Atomic Hot Cell Facility —F. L. Brown (GA)
17. *The Bettis Hot Laboratory — A. L. Maharam (W-BAPD)
18. *CANEL Hot Laboratory—R. V. Steele (PW-CONN)

General purpose manipulators and viewing

19. A Compact Manipulator—J. A. Brown, W. A. Koelsch, Jr. (ER)
20. A Radiation Stable Heavy Duty Electromechanical Manipulator — J. E. A. Graae *et al.* (ANL)
21. Hinged Arm Polar Manipulator Mounted on a Radio Controlled Mobile Base — W. C. Mohr, C. H. Youngquist (ANL)
22. Electrohydraulic Powered Bilateral Servomanipulator—R. S. Mosher (KAPL)
23. SETF Remote Viewing Technique—H. Burton (AI)
24. *Manipulator—G. P. Streechon (AI)

Hot laboratory operations and techniques

25. Operation of a Plutonium Cell—P. J. Peterson, J. L. Green (LASL)
26. Use of Solvent Soluble Films in Decontamination—F. J. Fitzgibbon *et al.* (LASL)
27. Changes in the Design and Operational Management of Battelle's Hot Cell Facility—E. C. Lusk *et al.* (BMI)
28. Experience in the Components Development Hot Cells at Atomics International —J. M. Davis, E. D. Grazini (AI)
29. Inspection of Irradiated Materials at Dounreay—E. Edmonds, K. M. Swanson (DERE)
30. Mechanical Processing of Spent Power Reactor Fuels—C. D. Watson *et al.* (ORNL)
31. *Decontamination Evaluation Facility—G. E. Neibaur (GE-HAPO)

Shielding and experiments

32. Chemical Processing of a Plutonium Fuel Element of the MTR Type—P. R. Fields *et al.* (ANL)
33. Attenuation of Cobalt-60 Gamma Radiation through Air Ducts in Concrete Shields—F. X. Rizzo *et al.* (BNL)
34. Remote Assembly of Reprocessed Fuel Subassemblies for EBR-II—R. H. Olp (ANL)
35. Remotely Controlled Hot Storage Cell for High Level Radioactive Samples—G. Boehme (KR)
36. Gamma Activity Scanning as a Tool to Obtain Burnup Contours—R. J. Burian, D. N. Sunderman, J. E. Gates (BMI)
37. Improved Facsimile Technique for Remote Metallograph—K. R. Janowski (AI)
38. Gamma Ray Attenuation of Shielding Windows—V. Culler (CGW)
39. Equipment and Techniques for Gamma Scanning Irradiated Reactor Fuel Materials—D. B. West, J. B. Newton, E. D. Grazzini (AI)
40. *Equipment for the Collection and Pressure Measurement of Fission Gases from EGCR Capsules—M. T. Morgan, M. F. Osborne (ORNL)
41. *A Fission Gas Collection System—R. E. Womack (GE-APED)
42. *Evaluation of Uranium Shielding in the Transportation of Radioisotopes—J. S. Lichliter (UC-B)

Glovebox design and specialized equipment

43. Modification and Repair of the HRE-2 Core Vessel—E. C. Hise, Jr. (ORNL)
44. Pressure Regulation in Activity Enclosures—J. Stafford Peck (UC-B)
45. A Remote Low Temperature Tensile Test Facility — S. B. McRickard, J. G. Y. Chow (BNL)
46. Atmosphere Handling and Control for a Glovebox Facility—L. F. Coleman *et al* (ANL)
47. Low Cost Gloveboxes—R. R. Malecha *et al.* (ANL)
48. Simple, Rapid Welder for Plastic Bags and Sleeves — H. P. Cantelow, L. E. Miles, B. D. Abram (UC-B)
49. Alpha-Gamma Containment Box—C. H. Youngquist *et al.* (ANL)
50. *Description of the High Activity Gamma Spectroscopic Analysis System at Handford—W. H. Zimmer (GE-HAPO)
51. *Facilities at Hanford for the Manufacture of Plutonium Ceramic Fuels—J. B. Burnham, Jr. (GE-HAPO)
52. *Simplified Filter Change without an Interrupted or Unfiltered Exhaust—R. A. Blomgren (ANL)

*For publication in the Proceedings.

No Nuclear Power *Reactor Data Sheets were returned from Russia for the January World Reactor Chart, but in his first article for a technical periodical outside Russia the head of the Atomic Energy Committee gives new details of his programme.*

REACTORS IN THE SOVIET UNION

by Professor VASSILY EMELYANOV, Chairman, Atomic Energy Committee, USSR Council of Ministers

THE SOVIET UNION has huge reserves of fossil fuels—coal, oil, and natural gas. It also has large resources of water power, especially in Siberia. Therefore, it is only natural that the current Seven-Year Plan concentrates mainly on thermal power plants and hydro-electric stations. Indeed, the share of atomic power is a modest one in the plan. The point is that the Soviet Union does not currently seek to augment the country's power supply through large atomic power plants.

The objective rather is to study and test various types of nuclear power reactors and to determine in this way which of them are most promising technologically and economically. The short-term plans for research work have been drawn up accordingly.

There is a wide diversity of approach, scale and progress in the nuclear reactor field in the Soviet Union. Research, development and engineering covers power reactors, traction reactors, and marine propulsion reactors in particular.

POWER REACTORS

Apart from the two operational nuclear power stations, the first completed in July 1954, and the second commissioned in Siberia in September 1958, two more major nuclear power stations are being built; at Beloyarsk in the Urals and near Voronezh. Also, Soviet specialists are co-operating with Czechoslovakian and East German scientists and engineers in the construction of two more nuclear power stations in Czechoslovakia and in the German Democratic Republic.

The reactors to be installed at the stations now under construction differ both in design and power output.

Voronezh reactor

This will be a 760 MWt output reactor using light water both as the heat-transfer agent and moderator. The active core of the reactor is enclosed in a pressure vessel 2·5 m (8·2 ft) high and 3 m (9·8 ft) in diameter. The active core is made up of fuel elements held in tubular cans.

The fuel elements are rods 10·2 mm (0·44 in) in diameter with a uranium dioxide slug 8·8 mm (0·35 in) in diameter. The active length of the fuel elements is 2·5 m (8·2 ft). Both the elements and cans are clad with niobium-zirconium alloy. The fuel is 1·5% enriched uranium.

Heated to 250°C and compressed to 100 atmospheres, the water leaves a steam generator to enter the annular slot between the reactor shell and active core. Flowing down, it then washes the fuel elements in an upward flow and emerges from the reactor heated to 275°C to be fed into the steam generator again. The inlet steam pressure in the turbine is 29 atmospheres.

Beloyarsk reactor

It is similar in design to the First Station reactor, but its output is 285 MWt.

The reactor is a large block of graphite with an active core 6 m (19·7 ft) high and 7·2 m (23·6 ft) in diameter, pierced with vertical channels which hold steel pipes with fuel elements inside them.

The channels are identical to their counterparts in the first station reactor. As distinct from it, about three-fourths of the fuel elements in the Beloyarsk reactor are cooled with boiling water, and the rest with steam supplied by the steam generator. The fuel is 1·5% enriched uranium; the steam from the reactor enters the turbine pressurized to 90 atmospheres.

Czechoslovak reactor

The reactor has a heat output of 590 MW. The moderator is heavy water, while carbon dioxide compressed to 60 atmospheres serves as the heat-transfer agent. The active core is enclosed in a steel shell 19 m (62·3 ft) high and 5 m (16·4 ft) in diameter. The wall in the cylindrical section is up to 140 mm. The reactor 'burns' natural uranium. Carbon dioxide enters the reactor at about 100°C and leaves it heated to approximately 425°C.

East German reactor

The heat output of the reactor is 265 MW. Light water acts as both the moderator and coolant. The core is shielded with steel, and the temperature of the incoming water is 250°C and of the outgoing water, 267°C.

The fuel is uranium oxide enriched to contain up to 1·5% uranium-235.

The fuel elements are clad with niobium-zirconium alloy.

REACTORS IN 'LENIN'

The nuclear reactors installed on board the ice-breaker *Lenin* use light water as both the moderator and coolant. Each reactor is rated at 90 MWt output. The reactor is enclosed in a steel vessel which also acts as a component of the biological shield.

The reactors' structural elements are designed to withstand high internal pressures and simultaneously meet a requirement vital for an icebreaker—to stand heavy vibration and impact loads, rolling and pitching.

The reactor is a vertical cylinder holding the active core and control rods. The outside diameter of the reactor vessel is 2 m (6·56 ft), while the height is 5 m (16·4 ft). On the inside, the vessel is plated with stainless steel to protect it against the corroding action of extremely hot water.

The fuel is uranium oxide enriched to contain 5% of uranium-235. Water enters the reactor at 248°C and leaves it at 325°C. The fuel elements are clad with zirconium alloy.

In 1960, the ice-breaker *Lenin* made

her maiden voyage in the Arctic ocean and stood up well to the rigours of the North. Further efforts in the field of nuclear propulsion will be made after the experience of the *Lenin* has been thoroughly analysed.

RESEARCH, TRAINING, ETC.

A whole range of reactors have been developed in the Soviet Union for research, isotope production, testing of materials, and training purposes. Most of them were reported at the 1st and 2nd Geneva Conferences.

Two types of these reactors—the VVR and the ITR-1000—have been built both in the Soviet Union and in some other countries.

Outside the Soviet Union, VV reactors have been built in Poland, the German Democratic Republic, Rumania, Czechoslovakia, and Hungary. A similar type will be soon completed in the United Arab Republic.

The first IRT-1000 reactor was built at the Atomic Energy Institute in Moscow. The official inauguration ceremony was held in November 1957, when Professor F. Perrin, the French High Commissioner for Atomic Energy, started the reactor.

Currently, another IRT-1000 reactor is nearing completion in Bulgaria. Ground has been broken for a similar reactor in Iraq and a contract for another has been signed with Indonesia.

In a water-water reactor, light water serves as both the moderator and coolant. Soviet designers have developed a whole family of these ranging in heat output to 10 MW.

The IRT-1000 swimming-pool reactor uses uranium oxide 10% enriched in uranium-235. Originally its heat output was 1 MW. At present, its rating has been raised to 2 MW.

Among research reactors, mention should be made of three units using heavy water as the moderator and natural uranium as fuel. One of them, rated as 2·5 MWt output, has been installed at the Institute of Experimental and Theoretical Physics in Moscow, another in People's China, and the third in Yugoslavia, with a heat output of 10 MW.

OTHER REACTOR TYPES

A good deal of attention in the Soviet Union is devoted to fast reactors. The greatest advantage of this type of reactor is that uranium is completely utilized. Practically all of uranium-238 is turned into plutonium. Another advantage of fast reactors is the possibility of using thorium.

The first zero-power fast reactor in the Soviet Union was built over six years ago. Another fast reactor rated at 5 MW heat output was started at the First Atomic Power Station in July 1958. Design work has been completed on a fast reactor of 50,000 kW electric power output.

Research and development is also well ahead on still other types of reactors in which use will be made of organic and gaseous coolants, with fuel in the form of solutions, suspensions, gas, etc.

Apart from reactors used for fundamental and applied research in physics, much headway has been made in the field of reactors employed for testing structural materials. Special emphasis to date has been laid on the response of austenitic stainless steel, zirconium alloys and low-carbon steels to irradiation.

The construction and operation of large atomic power plants coupled with further research and development will enable Soviet scientists to draw up a realistic plan for building reactors to be used in power generation as well as for traction and propulsion.

SOME RUSSIAN DESIGNED REACTORS*

NAME AND LOCATION	OUTPUT Thermal, MWt Net, MWe (No. of reactors)	MAX NEUTRON FLUX, n/cm²s (Thermal)	FUEL type, wt. (U-235 where enriched) (enrichment) form, cladding (cladding temp., °C)	COOLANT type, pressure, (lb/in² a) temp. (°C)—in, out. Flow (lb/min),(heat exchangers)	TURBINE CONDITIONS temp (°C) press. (lb/in² a)	DATE CRITICAL (actual or estimated), MODERATOR AND NOTES
Power reactors						
APS-1,Obninsk, Moscow	30t 5e (1)	5×10^{13}	U/9% Mo/12% Mg (by wt.) (5%), tubes, ss	H_2O, 1420, 190, 300		**'54,** C; has operated boiling and with superheat
Siberian power station, Troitsk	600e (6)		Nat. U, 200t, Al	H_2O, —, 220	1805, —,	**'58,** C; 1st reactor critical
VVER-210, Voronezh	1520t 420e (2)	10^{13}	UO_2 pellets, 40t, (1·5%), rods 10·2 mm dia., Nb-Zr	H_2O, 1470, 250, 275, 1,000,000 (6)	—, 29 atmos.	**'61,** H_2O; active length of fuel elements 2·5 m
Beloyarsk, Urals	1140t 400e (4)		U, 90t, (1·5%), tubes	boiling H_2O, 2100, 355 superheat 1470, 530	480, 1320	**'61,** C; similar to APS-1. Three-quarters cooled by boiling water the rest by steam. Active core 6 m high, 7·2 m high
KS-150 Czechoslovakia, Bohunice	590t 150e		nat. U pins, Mg/Be alloy	CO_2, 885, 100, 425, 210,000	400, 29 atmos. 180, 2 atmos.	**'65,** D_2O; Dual pressure steam
Atomkraftwerk 1, Neuglobsaw, E. German Republic	265t 70e (1)	10^{13}	UO_2 (1·5%), pellets in rods, Nb-Zr	H_2O, 1470, 250, 267, 426, 220 (9)	135, 29 atmos.	**'62,** H_2O; Core shielded with steel
Lenin	180t (2)		UO_2 pellets, 85 kg, (5%), Zr alloy	H_2O, 2850, 248, 325, 36,670	310,	**'59,** H_2O; full power 44,000 s.h.p. One spare reactor
Research reactors						
IRT-1000 Atomic Energy Institute, Moscow	2	$1·2 \times 10^{13}$	UO_2 (10%)	H_2O		**'57,** H_2O; also in Sofia '61, Iraq (cons. started), and Indonesia (contract signed)
VVRS Atomic Energy Institute, Moscow	2	2×10^{13}	U, 6 kg (10%), rods, Al (95)	H_2O, —, 34, 36, 36,600		**'53,** H_2O, pool type; 0·5 × 0·5 m core, elements 500 mm × 6 mm dia., 16 rods per element. For training isotopes, physics and biology experiments. Also in Prague '57; Dresden '57; Warsaw '58; Budapest '60; Egypt '61(?)
TVRS Peking, China	10	$7·4 \times 10^{13}$	U, 340 kg (2%), tube, Al (90)	D_2O, 40, 58, 390 m³/h (2)		**'58,** D_2O, R:C (26 t), 130 mm square lattice, 84 rods (1200 mm long), control rods: 7 shim, 2 automatic, 2 safety. Also in Belgrade '59.

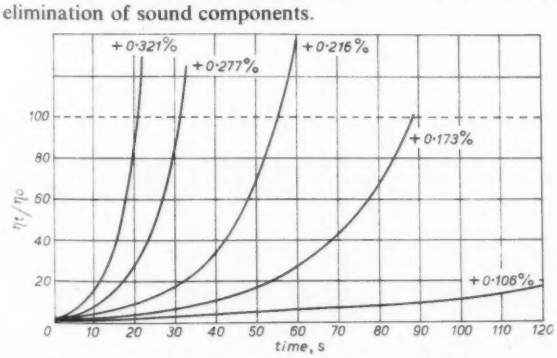
**Figures in this table are taken from Prof. Emelyanov's article above,* Nuclear Power *data sheets completed by the operators for Atomkraftwerk-1, VVRS and TVRS, and the latest published figures*

Carefully designed special purpose analogue computers compete advantageously with general purpose types for the applications outlined below

Solution of reactor dynamic equations

by W. A. HAVRANEK, A.M.I.E.E., M.I.R.E., Chief Project Engineer, and
T. M. KIERANS, Design Engineer, Reactor and Computer Division, Miles Electronics Ltd

IT IS AN ESTABLISHED fact today that computers are an indispensable engineering and operational aid. Analogue computers are finding increasing use for dynamic computation work and real time simulation in reactor engineering (*1–17*). For this reason a special purpose computer has been developed by the authors' Company. This computer consists of a special and a general purpose section, (*13, 18*). The special purpose section contains basically a 'neutron density computer (reactor power)' and a 'xenon poisoning computer' whilst general purpose units are used for heat transfer computation and other auxiliary specifications. The accuracy of utilizing amplifiers with summing and integrating components has been examined (*17*) and it was therefore only necessary, because of their circuit complexity, to analyse in detail the kinetic and poisoning computers and compare the results obtained with machine results. This comparison has established the accuracy of all modules in the computer and a closed loop calculation can therefore be relied upon to be computed with this accuracy. Thus, the information obtained is essential for checking out computers at the plant and as a routine check before vital computation work begins. A closed loop program is then given to the machine and the accuracy of the result compared with the machine 'standard answer.' This test is repeated to ensure that no machine error developed during the work period. If any deviation does occur in plant check-out 'start' or 'finish' tests, the computer sections are examined individually and the fault located by elimination of sound components.



2 decades

β_1 = 84·4%	= 2·11 × 10^{-4}	β_4 = 84·3%	= 2·53 × 10^{-3}
β_2 = 93·3%	= 1·4 × 10^{-3}	β_5 = 64%	= 7·36 × 10^{-4}
β_3 = 56·5%	= 1·26 × 10^{-3}	β_6 = 44·5%	= 2·67 × 10^{-4}

(l^* = 6·5 × 10^{-5}/s)

Theoretical response for positive δk steps (Fig. 1)

Reactor kinetics

Reactor dynamic behaviour is approximately given by:

$$\frac{dn}{dt} = \frac{\delta k - \beta}{l^*} n + \sum_{i=1}^{6} \lambda_i C_i + s \qquad (1)$$

$$\frac{dC_i}{dt} = \frac{\beta_i}{l^*} n - \lambda_i C_i \qquad (2)$$

The equations are derived from partial differential equations by finite difference approximation and may be proven by steady state equations. For a transient response analysis the equations may be solved for $n(t)/n(o)$ by laplace transformation where

$$\frac{n(t)(p)}{n(o)} = \frac{l^* + \sum_{i=1}^{6} \frac{\beta_i}{p+\lambda_i}}{pl^* - \delta k + \sum_{i=1}^{6} \beta_i \frac{p}{p+\lambda_i}} = \frac{M(p)}{N(p)} \qquad (3)$$

is derived.

Roots are then given by $N(p) = 0$ and coefficients by $M(p)/N(p) = A = 0$ (δk constant)

then

$$\frac{1}{A} = 1 - \frac{p \sum_{i=1}^{6} \frac{\beta_i}{(p+\lambda_i)^2}}{l^* + \sum_{i=1}^{6} \frac{\beta_i}{p+\lambda_i}} \qquad (4)$$

also from

$$N(p), \delta k = p\left(l^* + \sum_{i=1}^{6} \frac{\beta_i}{p+\lambda_i} \right) \qquad (5)$$

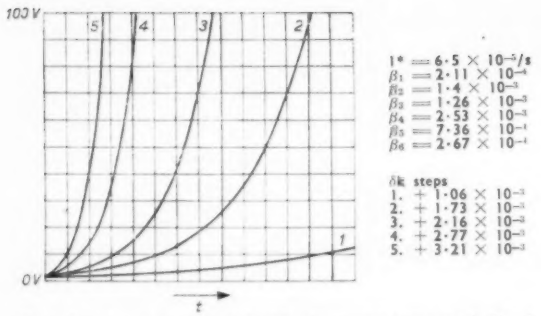
to give the corrected value of δk

The reactor doubling time = 0·693/p

p, δk, A, doubling times and responses $A_1 e^{p_1 t}$ were calculated and, using MERLIN as the example reactor, plotted as shown in Fig. 1. Machine results are given in Fig. 2 for accuracy comparison and a 9 decade result is available on an automatic rescaling facility.

A simulation with a 'mean' 1 delayed neutron group approximation is often used on general purpose computers. With the same values as in the '6 group' model,

i.e.:	$\beta_1 = 2{\cdot}11 \times 10^{-4}$	$\lambda_1 = 1{\cdot}245 \times 10^{-2}$
	$\beta_2 = 1{\cdot}40 \times 10^{-3}$	$\lambda_2 = 3{\cdot}05 \times 10^{-2}$
	$\beta_3 = 1{\cdot}26 \times 10^{-3}$	$\lambda_3 = 1{\cdot}114 \times 10^{-1}$
	$\beta_4 = 2{\cdot}53 \times 10^{-3}$	$\lambda_4 = 3{\cdot}02 \times 10^{-1}$
	$\beta_5 = 7{\cdot}36 \times 10^{-4}$	$\lambda_5 = 1{\cdot}136$
	$\beta_6 = 2{\cdot}67 \times 10^{-4}$	$\lambda_6 = 3{\cdot}01$



Two decade response obtainable, for comparison with Fig. 1, the paper speed is 2 in/min (Fig. 2)

$$\beta = \sum_{i=1}^{6} \beta_i = 6{\cdot}4 \times 10^{-3}$$

$$\bar{\lambda} = \frac{1}{\tau} = 7{\cdot}68 \times 10^{-2}, \text{ where } \tau = \frac{\sum_{i=1}^{6} \beta_i \tau_i}{\sum_{i=1}^{6} \beta_i}$$

and $l^* = 6{\cdot}5 \times 10^{-5}$

The equations are now

$$\frac{dn}{dt} = \frac{\delta k}{l^*} n - \frac{\beta}{l^*} n + \bar{\lambda} C \qquad (6)$$

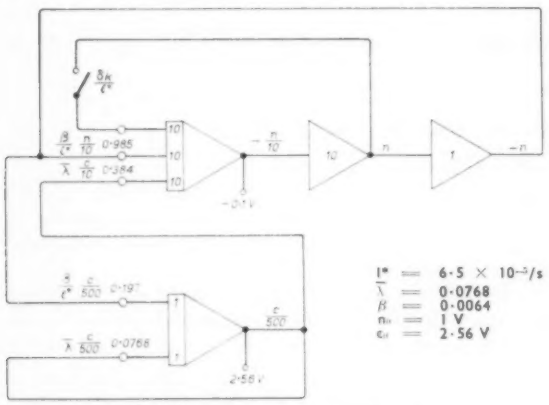
$$\frac{dC}{dt} = \frac{\beta}{l^*} n - \bar{\lambda} C \qquad (7)$$

For initial conditions $C_0 = \dfrac{\beta}{l^* \lambda} n_0 \qquad (8)$

For $n_0 = 1$, $C_0 = 1{\cdot}282 \times 10^3$

Since the general purpose computer with no rescaling facility covers ± 100 V only, equation (7) has to be divided by 500 in order to avoid overloading amplifiers.

Thus the initial condition of $C_0/500$ becomes a reasonable value (2·56 V) but on the program schematic the $C/500$ value has to be given the factor $-50\bar{\lambda}$ in order to feed $\bar{\lambda} C$ correctly scaled to the first integrator. To adjust the co-efficients of equation (6) on the potentiometer β/l^* for example = 98·452 would require a multiplication factor of 98·452. Since this would give overload conditions, equation (6) has been divided by 10. This means that the output of the integrator is now $n/10$. Figure 3 shows the programming schematic with the appropriate computer coefficients.



Programming schematic for one-group model (Fig. 3)

The equations were solved on General Purpose Units of the machine and the results are given in Fig. 4. The comparison with the previous result shows that the error is of quite a large order. It can be readily seen that this error would of course increase if more decades could be covered on the G.P. computer. Again using a mathematical transient response analysis the time to cover two decades has been calculated. This served as a check on machine accuracy.

Another method of utilizing General Purpose Computer modules for Neutron Kinetic Solution is given by logarithmic transformation of equations (1) and (2). This transformation quoted in detail in (*13*) converts equations (1) and (2), these now become

$$\frac{d}{dt}(\log n) - \frac{\delta k - \beta}{l^*} - \sum_{i=1}^{6} \lambda_i Y_i - \frac{s}{n} = 0 \qquad (9)$$

$$\frac{dY_i}{dt} + Y_i \left(\lambda_i + \frac{d}{dt}(\log n) \right) - \frac{\beta_i}{l^*} = 0 \qquad (10)$$

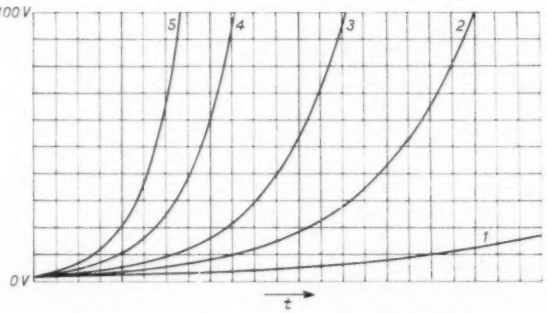
where $Y_i = C_i/n$

Programming these equations on a G.P. computer will yield results up to 10 decades of equal accuracy on a logarithmic scale. This computation requires 19 operational amplifiers, 2 servomultipliers and associated equipment for zero power reactor simulators. Using an American high precision analogue computer N. J. H. Schuch of the Institutt for Atomenergi, Kjeller, Norway, has shown that with such a model for a zero power reactor inaccuracies of up to 9% occurred. These are due to the small bandwidth of the servo multipliers and their insensitivity to small inputs. Substitution of electronic multipliers only made matters worse due to the insensitivity of these devices to small inputs. A detailed comparison of our special kinetic computer accuracies with this more conventional method will be discussed elsewhere.

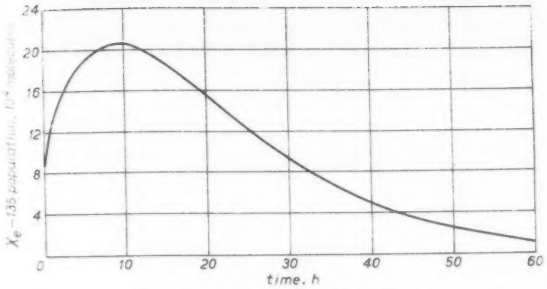
The calculations and tests have shown that a special purpose computer will give the solution to the reactor kinetic equations in the most accurate form over as many decades as are required.

Xenon poisoning

The poisoning of the reactor at a point in the fuel is described by two differential equations, neglecting the effect



Response obtained from one-group model; the paper speed is 2 in/min (Fig. 4)



Theoretical response for Xe-135 ' peak-poisoning ' after step shutdown (Fig. 5)

of samarium which is 2 decades smaller than for xenon.

Considering a step function at $t = 0$ reducing ϕ by many decades, e.g. sudden shut down. Then at

$t = 0^-$ $\phi = \phi_0$ and $\Sigma_f \phi = \Sigma_f \phi_0$

$t = 0^+$ $\phi = 0$ and $\Sigma_f \phi = 0$

The equation derived by laplace transformation for xenon becomes

$$X(t) = X_0 e^{-\lambda x t} + \frac{\lambda_I}{\lambda_X - \lambda_I} I_0 (e^{-\lambda I t} - e^{-\lambda x t}) \qquad (11)$$

Using coefficients associated with MERLIN the theoretical response curve is given in Fig. 5. Figure 6 gives the result obtained using 2 servo integrators on the computer in a speeded up time scale operation (1 s ≡ 1 h).

Providing the reactor has been run for a time greater than 50 h at constant power, poisoning will be at an equilibrium value at the time of shut down. This equilibrium value will give X_0 and I_0 obtained by equating dX/dt and dI/dt to zero.

Then
$$I_e = \frac{\gamma_I \Sigma_f \phi}{\lambda_I} = I_0 \qquad (12)$$

and
$$X_e = \frac{\Sigma_f \phi (\gamma_I + \gamma_X)}{\sigma_X \phi + \lambda_X} = X_0 \qquad (13)$$

this gives for MERLIN, where

$\gamma_I = 5{\cdot}6 \times 10^{-2}$ $\gamma_X = 3 \times 10^{-3}$

$\Sigma_f = 5{\cdot}9 \times 10^{-2}$ $\lambda_X = 2{\cdot}1 \times 10^{-5}$/s

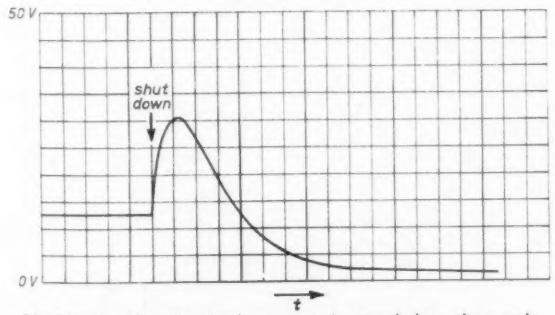
$\phi = 3{\cdot}4 \times 10^{13}$ n/cm² s (at 5 MW) $\sigma_X = 3{\cdot}5 \times 10^{-18}$

$\lambda_I = 2{\cdot}88 \times 10^{-5}$/s

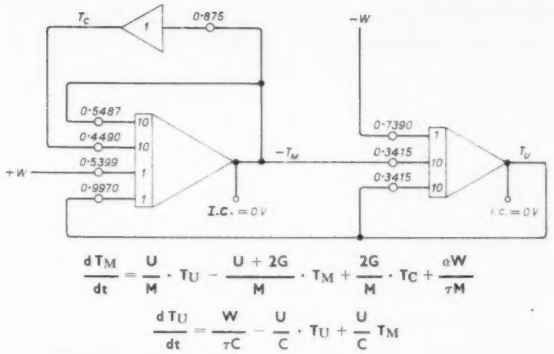
initial conditions of

$I_0 = 39{\cdot}005 \times 10^{14}$ atoms/cm³

$X_0 = 8{\cdot}454 \times 10^{14}$ atoms/cm³



Machine ' peak poisoning ' response in speeded-up time scale 1 s ≡ 1 h; the paper speed is 2 in/min (Fig. 6)



$$\frac{dT_M}{dt} = \frac{U}{M} \cdot T_U - \frac{U + 2G}{M} \cdot T_M + \frac{2G}{M} \cdot T_C + \frac{\alpha W}{\tau M}$$

$$\frac{dT_U}{dt} = \frac{W}{\tau C} - \frac{U}{C} \cdot T_U + \frac{U}{C} T_M$$

For MERLIN

C = 16·1 × 10³g for 3·5 × 10²g loading of U-235 (water equivalent of core)
M = 55·2 × 10³g (mass of core water)
G = 121 × 10³g/s (2 pumps) (coolant flow rate)
U = 5·5 × 10⁴ cal/°C s (heat transfer coefficient from uranium to water for whole core)
α = 2·8% (fraction of total fission energy released promptly into coolant)

Programming schematic for heat transfer simulation; all temperatures referred to lake temperature (assumed constant); scaling factors 0·5 V/°C, 10⁻⁵ V/W (Fig. 7)

For peak value, the time to Xe max is given by $\frac{d}{dt}X(t) = 0$ and t was calculated as 9·219 h. This gives Xe max = 20·601 × 10¹⁴ atoms/cm³.

The study of the xenon effects in the reactor is of great importance in reactor design and will play an important part in the operation of nuclear power stations (*19*). The analysis given shows that the units under consideration will give accurate results in such computing applications. An additional advantage of the system is that real time simulation is possible for control equipment testing or use as a ' memory ' for poisoning prediction. In such an application electronic integrators can be used for the ' predictor ' which operates in a speed up time scale.

Heat transfer

The heat transfer equations are dependent upon the reactor system under consideration and the accuracy required for the problem solution. It has therefore not been regarded advisable to develop special circuits for heat transfer simulation and general purpose computer modules are being used for this application. On simulator projects ' fixed ' to a particular reactor type, however, special heat transfer simulation units may be applied for economical reasons and in this case analysis of the sections, as for the neutron density and poisoning effects, will have to be undertaken. With the present arrangement the accuracy of all general purpose units employed was known and tested and such an analysis regarded as unnecessary. We have therefore limited ourselves, again using MERLIN, to showing how the heat transfer equations were derived, programmed on the machine, and have shown the results so obtained. For deriving the differential equations describing the uranium temperature one fuel element only is considered, which is made up of all others. Because the dynamic investigations are of a qualitative nature, such a method is reasonable, but an improvement can be derived if the lumped fuel element is divided into several sections and the differential equations expressed for each section. One can also consider that the heat generation along the fuel element is non-linear (cosine shape).

The derivation of the differential equations which describe the temperature behaviour of the fuel T_u, the coolant inlet temperature T_c, and the moderator temperature T_M leads to the equations shown in Fig. 9 for programming on the computer. The heat exchanger is described by the simple approximation:

$$T_c = \gamma T_M \qquad (14)$$

where $\gamma = 0{\cdot}875$.

For better simulation of MERLIN a time delay of 100 s (deactivation period) should also be incorporated in the computer heat exchanger program. The time delay unit, which will be utilized for lag simulation, is still in the development stage and was therefore not available for this work, but since the main purpose of this was to determine computer behaviour, the heat transfer characteristic simulation need not be fully representative of the MERLIN reactor. The initial conditions are given by stationary conditions:

$$\frac{dT_M}{dt} = \frac{dT}{dt} = 0$$

whence $T_M \simeq T_u \simeq 0$.

Figure 7 gives a programming schematic using coefficients appropriate for MERLIN. The results obtained on the machine are given in Figure 8.

Complete reactor system

The separate sections discussed were coupled to form an analogue of MERLIN under operating conditions, i.e. with temperature and poisoning effects present. In this arrangement the temperature and poisoning sections of the computer form a closed loop with the neutron simulator (*13*). In water moderated reactors the effect of temperature on reactivity is non-linear and for MERLIN given by the expression

$$\frac{d}{dT_M}(\delta k) = 10^{-5}(8{\cdot}15 - 0{\cdot}314T_M)/^\circ C$$

with units of $\delta k = 100\%$.

This relationship has been plotted and programmed on an electronic function generator. It is therefore considered in the loop test. The initial conditions for temperature were

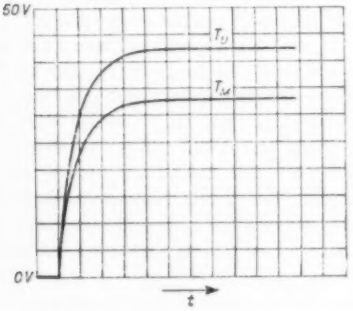
	$W_0 = 10^6$ W	W = 10 V
	$T_{M0} = 8{\cdot}1^\circ$C	= 4·05 V
	$T_{u0} = 12{\cdot}82^\circ$C	= 6·41 V
and	$W_0 = 5 \times 10^6$ W	W = 50 V
	$T_{M0} = 40{\cdot}5^\circ$C	= 20·25 V
	$T_{u0} = 64{\cdot}1^\circ$C	= 32·05 V

The driving function is reactivity and results for various step changes in reactivity are given in Fig. 9.

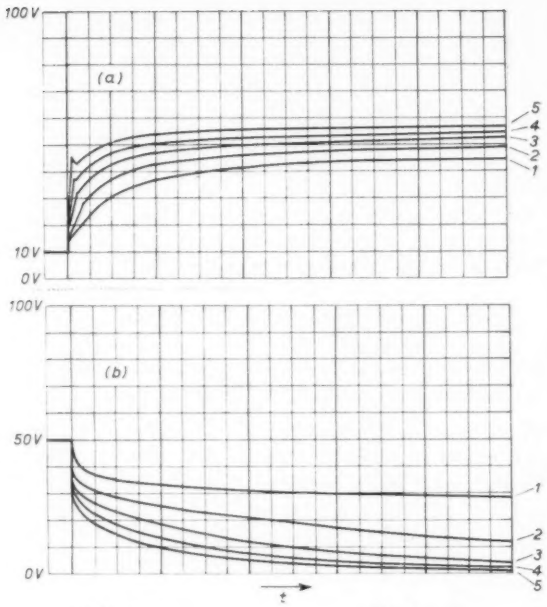
Conclusion

Individual section responses agreed with calculated data. In consequence the closed loop system response is accurate to similar limits and the machine suitable for analysis of various reactor systems. These can be extended to cover multi-zone power reactor simulation with detailed simulation of heat exchangers and generator loads.

The work also illustrates that special purpose computer sections will give results equal to or better than those obtainable on general purpose installations provided that they are carefully designed and functionally checked after manufacture. They provide, together with those advantages, computer economy and are indispensable in training simulators.



Response obtained from heat transfer simulation (T_M and T_u) as a result of step change in reactor power; paper speed 12 in/min (Fig. 8)



(a) δk steps
1. + 0·5 × 10⁻³
2. + 0·1 × 10⁻²
3. + 0·15 × 10⁻²
4. + 0·2 × 10⁻²
5. + 0·25 × 10⁻²

(b) δk steps
1. − 1 × 10⁻³
2. − 2 × 10⁻³
3. − 3 × 10⁻³
4. − 4 × 10⁻³
5. − 5 × 10⁻³

Transfer functions obtained from machine for step changes of reactivity with consideration of complete reactor loop; paper speed 2 in/min (Fig. 9)

Acknowledgments

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Designed for use primarily by the divisions of reactor engineering, chemistry and physics at Argonne National Laboratory JUGGERNAUT *is similar to the* ARGONAUT *in design except for modifications which allow higher power operation*

The Juggernaut reactor

DETAILS OF THE DESIGN of the latest Argonne reactor, the JUGGERNAUT, were presented to the meeting of the ANS held in San Francisco last December. When completed early this year it will be one of ten reactors used at Argonne for basic research. Its main use will be in developing nuclear instruments though it is considered of value in other areas of research such as analytical chemistry and electronics. Mr J. R. Folkrod of Argonne National Laboratory Reactor Engineering Division, who presented the paper, told *Nuclear Power* that 'the JUGGERNAUT will afford complementary facilities to those provided by CP-5. Experiments now in the CP-5 reactor will move over to the JUGGERNAUT for two reasons: (1) they do not require the elevated flux level in CP-5, (2) some experiments can be handled as well in the JUGGERNAUT and will relieve the space problem at CP-5'.

Experimental flexibility at low cost is provided by the use of removable shielding blocks. These make up about 60% of the shield; the rest is poured concrete. The thermal column is smaller than that for the ARGONAUT as it has been found by experiment that a large column is not necessary. With the small column the core becomes more dense and so allows a higher flux in the column. The reduction in core dimensions reduces the overall size of the reactor and the total cost.

The JUGGERNAUT is a thermal type reactor and has a flux of about 2×10^{12} n/cm² s at the core when operating at steady power. Dimensions are 3 m (9·84 ft) high and 6·4 m (21 ft) across the top. The core is contained within a 7·6 cm (1·2 ft) wide annulus formed by the thermal column and the pressure vessel. It consists of 20 assemblies each with 12 plates. As there is more space in the core than is required for fuel, dummy plates are used where fuel is not needed. The assemblies are positioned by a grid. There is no hold-down assembly as the water velocity is not great enough to dislodge the assemblies.

Control of the reactor is accomplished with seven window-shade type boron-steel shim safety rods. These are located in the reflector at an average distance of 4 cm (1·6 in) from the core face; they are similar to those on the ARGONAUT but the ribbon has been extended so that the mechanism is out of the high activation area, so allowing easy maintenance. The combined worth of these rods is 7·5% $\Delta k/k$. There is a single fine control rod with a rack and pinion drive. It is manually operated and the control section is cadmium.

Facilities

Four horizontal beam holes equipped with shutters
Ten vertical beam holes and two thermal columns equipped with gates
An internal thermal column with three experimental holes
A test cave
A universal facility

Experimental programmes

1 *reactor spectrum measurements*
2 *thermal fission counting, yield, cross-sections, etc*
3 *neutron diffraction work*
4 *dry shielding experiments*
5 *testing neutron measuring instruments*
6 *cold neutron technology*

JUGGERNAUT DATA

Type	light water moderated and cooled research reactor
Thermal output	250 kW
Thermal flux (max)	4×10^{13} n/cm² s
Total fuel loading at rated power	3·8 kg U-235
Enrichment	93%
Elements	plate type 7·3 × 66 × 0·178 cm, U/Al alloy, 16·7 g/plate, 12 plates/assembly, 20 assemblies
Cladding	Al (0·0508 cm)
Max cladding temp.	65°C
Coolant	H_2O
Pressure	15 lb/in² a
Temperature, in-out	20–35°C
Flow	1000 lb/min
Reflector	graphite (60 cm)

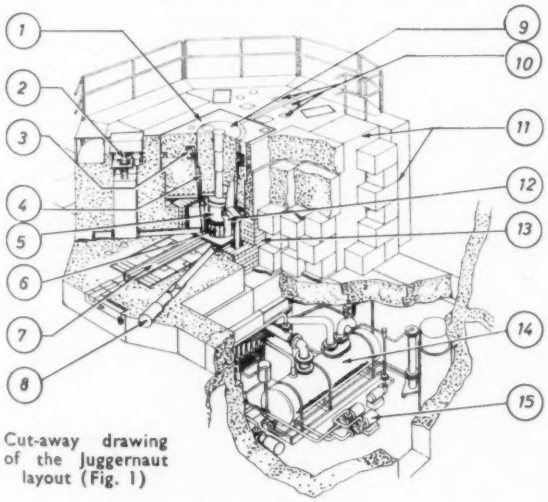
The most interesting of the twenty-two facilities available are the test cave and universal facility. It is possible to have a large tank of water in the test core and this would be irradiated by a plane source of neutrons 120 × 120 cm. The flux is 3×10^{11} n/cm² s and an experiment could be set up in this tank and worked on from above as in a pool reactor. The universal facility is similar to the test cave but is on a larger scale.

The thermal column is about 2 m (6·6 ft) deep and about 1·25 m (4 ft) square cross-section. The neutron gradient in the column is from 10^{12} to 10^{9} n/cm² s; the flux then abruptly changes to 10^{4} n/cm² s as it encounters a ¼-in thickness of boral. The central portion of the column is filled with stringers, the centre one of which can be removed, thus providing in effect another beam hole. The vertical experimental ports extend from the top of the thermal column graphite to the top of the reactor. There are five of these ports for each of the two columns and they range in size from 10–20 cm (4–8 in). The reactor also has four 6-in dia. beam holes equipped with motorized shutters. Two are near the core; the other two terminate at the thermal shield. The flux expected at the beam face is about 10^{6} n/cm² s.

The three experimental holes in the internal column are accessible from the top of the reactor. One is a 15 cm (6 in) hole in the centre; the other two, both 4·5 cm (1·8 in) are half-way along the radius and at the circumference.

The core cooling water flows at 8 l/s. After flowing upwards over the fuel plates the water goes to the dump-storage tank. From here it is pumped to the heat exchanger and back to the reactor.

The reactor is also provided with a clean-up system. Water is taken from one end of the dump-storage tank through an ion-exchanger and filter and then returned to the opposite side of the tank. As the cooling system is closed the water can be kept relatively clean.



1 removable centre shield
2 shutter mechanism
3 shim-safety drive
4 vessel seal
5 internal thermal column
6 reactor core
7 a thermal column
8 beam hole
9 rotating shield
10 vertical experimental ports
11 shielding blocks
12 vessel
13 universal facility opposite test cave
14 dump-storage tank
15 reactor pumps

Cut-away drawing of the Juggernaut layout (Fig. 1)

Cross Section by GRACCHUS

A THIRD primary separation plant for Windscale is now a distinct possibility. I have been told that the AEA's Production Group will have to expand its chemical plant capacity for processing irradiated fuel elements in step with the nuclear power programme. Because of this, plans are at present being formulated which will take into account the remaining useful life of the first separation plant at Windscale and the probable performance of the second plant now being built. This second plant, due to be in operation in 1963, will incorporate a new process using tributyl phosphate diluted with an inert hydrocarbon in horizontal box-contractors. It is suitable for treating the more highly irradiated civil reactor fuel elements and has higher efficiency than the first plant which uses the butex process. In addition, its capital and operating costs are substantially lower.

THE SECRECY which surrounded the 24 MW reactor being built in the Negev desert, south of Beersheba, rebounded with a vengeance on Israel. After repeated denials, it was finally admitted that this reactor was being built with French help and would be completed in three to four years time.

The sequence of events makes interesting reading. Early in December, the US Joint Congressional Committee on Atomic Energy held a special meeting at the request of the State Department and the Central Intelligence Agency. Long-range photographs had revealed that what was thought to be a textile factory was, in fact, a reactor. Requests were made to Israel for further information and then the news was leaked out on a television programme when the chairman of the AEC, Mr John A. McCone, said informal and unofficial information concerning the Israeli reactor had become available.

Then followed a spate of denials from Embassies in London and Washington, saying that Israel was not planning to make an atomic bomb and that the only reactor was the 1 MW research reactor at Rehovoth. It was only later that there was a reluctant admission from Prime Minister Ben-Gurion that this 'secret' reactor was being built. This came after it was admitted that Israel was co-operating with France in atomic research.

The whole matter has now died down but several questions still remain unanswered—and are not likely to be at present. The first is why all this 'peek a boo' secrecy was necessary? Why Israel, for instance, which is one of 40 nations which shares information on peaceful uses of atomic energy with the US, should not have mentioned the reactor till pressed? There is also, of course, the question of why the close co-operation between Israel and France should have been kept so quiet? Political reasons must have been a major factor in this secrecy but now, after all this hedging, bumbling and bad publicity, I wonder if it was all worthwhile?

THE NEW Year has brought home again to businessmen in Britain the pending economic division of western Europe. On New Year's Day, the first major steps were taken to set up a tariff wall round the Common Market countries—a tariff which commercially separates its six members from the rest of the world. It also saw increases in German and Benelux tariffs in the move towards a custom union. The organization has given notice that it is no longer a tender seedling but a plant set on its way to full growth.

The huge single market that will exist behind this tariff wall will be excluded from British products unless some action is taken soon. Mr Heath, Lord Privy Seal, with responsibility for European affairs, has indicated a leaning, somewhat obscured, towards Europe; however, he has so far skirted round the question of whether the UK should join the European Economic Community or merely identify itself with its purposes. Recent indications are that apart from a certain amount of reserve from the French, sentiment on the Continent is favouring a British move towards the Common Market. This followed the informal talks held last year in Bonn and Rome by Mr Macmillan and Mr Heath.

I now gather that Britain will have to make some gesture towards opening talks on an acceptable treaty governing its entry into the Common Market and that this move will have to come fairly soon. No doubt it will have to follow further talks with the Commonwealth countries and the European Free Trade Association. But further delays may well leave Britain outside this dynamic Community, for the Common Market is gathering momentum and may well have gathered so much speed by the time a positive approach is made, that there will be little willingness to accommodate changes for late entrants.

THE TIME of goodwill brought a spate of reports connected with radiation and fallout whose tenor, happily, was reassuring. This applies in particular to the Medical Research Council's latest report on radiation dangers—'The Hazards to Man of Nuclear and Allied Radiation'—which is the successor to a 1956 report issued when it was not altogether clear how dangerous small doses of radioactivity over a long period could be. It was assumed that these were as dangerous as the same amount received at one time. This is not so, the report concludes. Another fresh point is that liability to lukaemia after a large radiation dose diminishes after about ten years.

On Record

'The central job of nuclear energy—the development of a longe-range energy source, complete with waste disposal and chemical recycle, which will be available when we really need nuclear energy—this job, I submit, is not being attacked with full vigour and seriousness.'

Alvin M. Weinberg, Director of the Oak Ridge National Laboratory, in his annual State of the Laboratory speech.

'It is now fashionable in some quarters to decry the nuclear power programme and to run down the reactors now under construction before they have been started up.'

Sir Roger Makins, chairman of the UKAEA, opening the Ilford 'Atoms in Camera' exhibition.

Here is 'Nuclear Power's' quick reference guide to new equipment for the nuclear technologist

Physical Society Show—1961

Westminster, January 16 - 20

THE EXHIBITION of the Physical Society this year shows little significant change in equipment design. However the trend towards miniaturization, and the use of printed circuits and solid state devices continues at an accelerated rate. There is also a tendency towards a diversification and extension of the range of nucleonic and health monitoring equipment.

Government and official sponsored participation in scientific research and development is once again well demonstrated but the lack of representation from the Universities is disappointing. Possibly this is through an inherent suspicion that the show is becoming more and more a form of trade fair for industry and that the 'string and sealing wax' devices have no part in it. More representation of the important fundamental and applied research work that is being undertaken at universities could have a beneficial effect.

The original concept of the show in selecting only those intruments that are entirely new is weakening with each successive year. A fair proportion of the exhibits, now in production, were seen last year, and not necessarily in prototype form.

Nucleonic equipment

New in the range of portable instruments from **General Radiological** (Stand 3) for health monitoring and survey work, using solid state circuitry, are: the NE207 plastic scintillator dose ratemeter, using a new type of pulse amplifying and integrating circuit and providing a dose rate range 0·1–1000 mr/hr over an energy range 50 keV–3 MeV; the NE206 ionization chamber beta/gamma dose ratemeter, that incorporates an audible alarm 0·1–1000 r/h logarithmic scale and employs an electrometer triode and transistor d.c. amplifier; and the NE204 1–10,000 mr/hr logarithmic scale meter that uses a sub-miniature G.-M. tube reading over the range 60 keV to 3 MeV, reasonably independent of energy Already in production is the NE148 gamma scintillation monitor with illuminated dial, that uses a sodium iodide crystal and has a full scale deflexion of 0·03 mr/h on the most sensitive range.

Two new monitors from **EMI Electronics** (Stand 20), now in production, include the transistorized SM1 low activity sample monitor that responds to energy around 140 keV, and the single hand unit type HM2 that detects both alpha and beta simultaneously. The readings of the former are indicated by a double range linear ratemeter that provides full scale deflexions of 0·50 and 0·500 counts/sec. In the prototype stage, **Ekco** (Stand 30) have their complete gamma spectrometer that combines the N676 scintillation counter and the N600 ratemeter and gives better than 4 : 1 peak to valley ratio for Co-60.

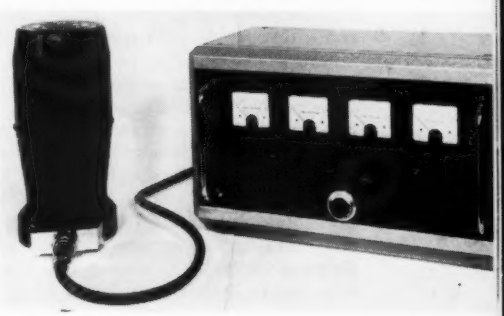
> One of the most useful shows of its kind for the presentation of new concepts, this year's Physical Society Exhibition follows the trend of last year with participation by over 100 private firms and some 40 or more official or government sponsored organizations.

Among the **Avo** (Stand 33) instruments demonstrated is a radiation level detection system that covers a number of points in a building for the detection of radiation levels from 0·1 r/h–500 r/h. The 1532A dose ratemeter, completely self-contained, measures radiation at a distance up to 16 ft. **Isotope Developments** (Stand 41) are showing applications of the 1880 dynamic capacitor electrometer that was exhibited last year. Applied to the charging and reading of BD11 ionization chambers, and working with a gamma sensitive chamber and chart recorder, very low levels of radioactivity can be measured. Using thin caesium iodide crystals, the 723 windowless scintiliation counter head, has been modified from its normal purpose of counting soft beta particles to the counting of alpha particles, with a resolution of approximately 4%.

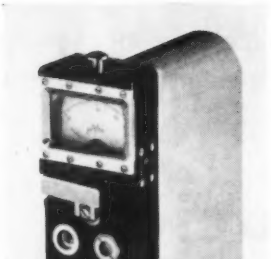
AEI (Stand 131) illustrate the work that is being done in developing single cadmium sulphide photoconductive cells; a standard type for general radiation monitoring, and a miniaturized cell small enough for intracavitary measurements of gamma ray dosage.

In addition to those already described, devices for the detection and counting of radioactive particles are again well represented. To comply with the requirements of the new Factory Ionizing Radiations Act, **Labgear** (Stand 106) are developing a universal dose ratemeter that incorporates an ionization chamber for the measurement in millirads/hr of alpha, beta and gamma and low energy -ray radiations. Also in the development stage is a new laboratory scintillation unit that embodies a 3-stage amplifier with cathode follower output. To the already extensive range of Geiger counter tubes available, **20th Century** (Stand 8) have added the SW12 unit for low energy beta counting with S-35 and C-14. Its use is complementary to the standard B12 beta-gamma counter. Under develop-

IODINE MONITOR—Nuclear Enterprises



GEIGER ASSEMBLY—Panax



GAMMA MONITOR
—General Radiological (above)

GLOVE CABINET
Townsend & Marcer (left)

ment is a miniature high pressure chamber with high insulation resistance, designed for use in integrating dose meters.

Ekco's (Stand 30) new manual scaler, type N667, which is shown in association with a type N662 round lead castle, a Geiger tube and preamplifier, has an input resolution of 2 microseconds.

In the development stage, **Panax** (Stand 85) have a high sensitivity scintillation flow counter that can detect 300 $\mu\mu$c/litre of strontium-90 against a background count rate of 1·5–2 c/s. They also have a mains operated switch that can be used with a variety of Geiger counters to monitor the radiation level in a selected situation, enabling an alarm to be given and control contacts to be operated. In production is the automatic counting equipment F600/6 that was shown in prototype form last year; high sensitivity low background Geiger counting equipment, with typical background rates of the order of 1·5 c/min; and a complete tritium counter composed of an automatic counter type F600, a liquid scintillation counter type SC-LP, and a refrigerator unit type RU1660.

EMI's (Stand 20) production-line beta probe BP4 is a scintillation counter intended primarily for the detection of low energy radiation. The phosphor is anthracene evenly deposited on a polyvinyltoluene light guide, optically coupled to a type 9542S photomultiplier tube. Two new items of counting equipment added by **Ericsson** (Stand 115) are the universal scintillation head type 214A, fitted with an 11-stage photomultiplier tube, and the coincidence/anticoincidence unit that has a resolution time of around 2 microseconds and is able to drive a scaling unit or ratemeter.

The latest glass scintillator to be introduced by **Nash and Thompson** (Stand 40), GS1, is a lithium alkaline earth silicate glass activated by cerium. It is chemically inert and can be used in contact with strong nitric acid solutions of radioactive materials. **Nuclear Enterprises** (Stand 61) are showing their complete range of scintillation phosphors which includes the new NE150 plastic phosphor with excellent pulse shape discrimination properties. Also new is the range of integral and demountable NaI(Tl) crystal-photomultiplier head units (see Nuclear Power, December 1960, p. 118). Photomultiplier tubes now in production by **20th Century** (Stand 8) include the RBMS10/14 developed under contract to the AWRE, and the VMP 11/170, a tube with large cathode area combined with uniform cathode sensitivity. The five-stage image intensifier tube, developed in cooperation with the Admiralty and Imperial College, has now reached the production stage. It produces a picture diameter of 19 mm with a resolution of 14 line pairs/mm. **EMI Electronics** (Stand 20) are continuing with the development of photomultiplier tubes. They now have a 5 in diameter tube with a high speed of response; another is on the way that has an extremely fast rise time and high output current.

New designs in ancillary equipment cover such laboratory units as gloveboxes, isotope carriers and sample changers. A sample changer under development for the AERE by **Isotope Developments** (Stand 41), type 2014, can handle up to 50 samples of isotopes mounted in standard 1 in planchets, and works in conjunction with a 1700 scaler with the count and time of count for each sample printed on paper tape. In production is the isotope carrier 6003 with heavy lead shielding and designed for easy transportation. A sample changing mechanism is incorporated in **Labgear's** (Stand 106) prototype shielded anticoincidence counting assembly. An associated coincidence/anticoincidence unit offers two outputs of opposed polarity with metal indication, together with a fully resettable plug-in 5-decade counter.

Fitted with exhaust pumps and Harwell type filters, the latest version of rigid glove box by **Townsend and Mercer** (Stand 94) incorporates an improved moulded window gasket to give a cleaner line. For operating in a controlled atmosphere, **Gallenkamp** (Stand 128) have introduced a glove box with an air lock and with stopcocks to control the inlet and exit pressures of gas. An interesting radioactivity application is the use by the **Warren Spring Laboratory** (Stand 47) of a radioactive rotameter float for recording low rates of fluid flow at high pressures. The position of the float is detected by Geiger tubes. Another new technique is the use being made by the **British Steel Castings Research Association** (Stand 47) of tracers to study the origin of inclusion in steel castings.

For industrial applications, **Ekco** (Stand 30) have two nucleonic gauges under development. The N680 moisture gauge is designed for operation at the 'dry-end' of paper-making machines; the other is a memory unit which, principally designed for coating applications, retains a reading at any pre-set time up to 5 min, enabling the reading from the base material to be compared with a reading from a second gauge monitoring the coated material.

For the production of short-lived isotopes and for other research a number of neutron generators are now available. A prototype unit shown by **20th Century** (Stand 8) operates under d.c. conditions and produces fluxes of 10^{10} neutrons/s, employing the (D, T) reaction. **Mullard** (Stand 134) have under study a compact accelerator neutron source that consists of a sealed-off tube and auxiliary power supplies. Within the tube, deuterium and tritium ions, that are generated by a Penning ion source, are accelerated in a single stage up to 125 keV. They

strike a titanium plated self-loading target releasing neutrons of 14 MeV; saturation of the target maintains itself throughout the whole life of the tube. From the **Services Electronics Research Laboratory** (Stand 135) comes a new form of fast neutron source capable of giving 10^8 neutrons in a 20 μs pulse at 1 pulse/s. It may also be run continuously at a level of 10^7 neutrons/s.

In conjunction with the UKAEA high temperature reactor projects, a number of fission chambers have been designed by **20th Century** (Stand 8), types FC08/1000 and FC02/1000, for operation at 600°C and FC538/100 for operation to 850°C.

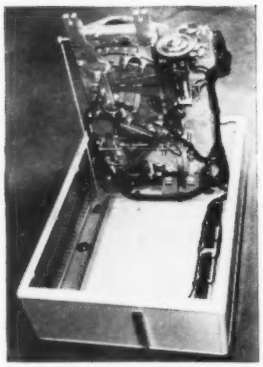
Pulse instruments

Of value in programming computers is the **Nagard** (Stand 42) type 5101 pulse group generator whose primary function is to generate groups of trigger pulses, with adjustment over a wide range of characteristics made possible by use of continuously variable and calibrated controls. Variable, are the length of groups within the values 20 μsec–0·2 s and the pulse frequency of 10 c/s and 100 kc/s. Another instrument designed to speed the development of computers and all pulse-operated equipments, is the **Wayne Kerr** (Stand 102) P131 pulse generator. It provides pulses of 50, 75, 100, 250, 500 750, and 1000 mμs, with rise and fall times of less than 15 and 20 μs respectively.

In the prototype stage is the pulse generator GO1005 from **Solartron** (Stand 111) that provides single or double rectangular pulses with amplitudes up to 100 V peak at pulse repetition frequencies between 10 and 10^6 pulses/s, with pulse durations ranging from 200 mμs to 10 ms. The **Marshall** (Stand 117) twin channel pulse generator type TPG 102, that was shown last year in prototype form, has now reached the production stage and claims extreme accuracy in all parameters. Another generator, under development by **Cossor** (Stand 121), is the 1097 development of the original model 1046 that uses a high pressure mercury relay to produce pulses of rise time less than 1 mμs of continuously variable amplitude up to 100 V.

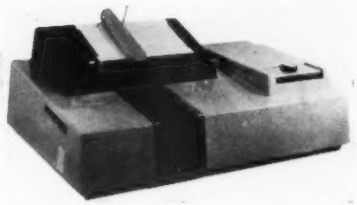
Among the pulse height analysers exhibited is the new **Plessey** (Stand 35) 99-channel equipment, designed at the AERE, that can also be applied as a time-of-flight spectrometer. Auxiliary control units can be used in conjunction with a decimal printer or a card punching machine. With a resolution time better than 1·5 microseconds. **Isotope Developments** (Stand 41) now have in production an 1870 single channel analyser. Threshold bias is continuously adjustable, monitored by the front panel meter, over the range from 5 V to over 50 V positive. The demonstration shows its application to plotting an alpha particle spectrum using a 6001 windowless scintillation counter, the pulses from which are amplified by a 668 linear head amplifier.

New in the oscilloscope line is the differential double beam unit from **Furzehill** (Stand 10) that has two identical vertical amplifiers, providing differential output on each channel feed. A modified version of the model 301 shown last year is being developed by **Nagard** (Stand 42) to incorporate a sweep delay circuit with selected brightening of the portion of the waveform to be examined in detail. Their two-channel wide-band oscilloscope, Model 321 has been designed around a new type of double-gun cathode-ray tube that incorporates a helical post-deflexion acceleration system operating at 10 kV. High intensity of display enables single transients at high speeds to be recorded. **Airmec's** (Stand 46) type 294 oscilloscope is a high speed unit particularly suitable for the observation and photography of fast rising pulses with a low repetition rate. **Solartron** (Stand 111) are showing two prototypes: the CD 1012 general purpose oscilloscope with a

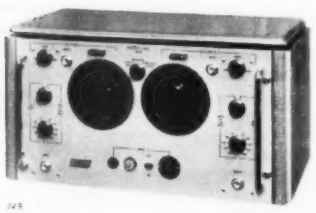


MECHANICAL ANALOGUE—Elliott (above)

DIGITAL VOLTMETER—Venner

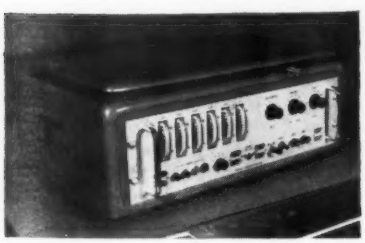


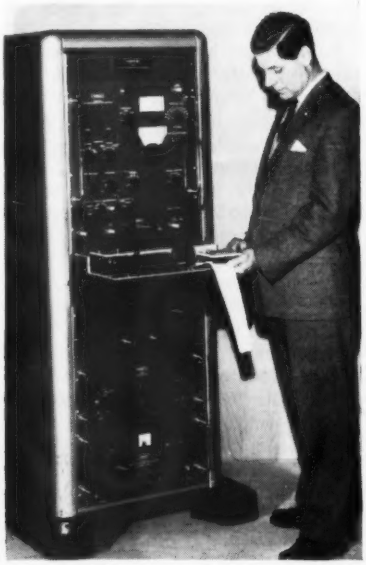
SPECTROPHOTOMETER—Unicam (right)



FILTER UNIT—Cawkell (above)

SCALER 200—Marshall (below)





WAVE ANALYSER—Muirhead

SALINITY BRIDGE—Wayne Kerr (left)

PULSE GENERATOR—Planer (above)

10 cm × 6 cm display area operating at 14 kV; and a small portable single-beam unit CD 1015 with a bandwidth from d.c. to 12 mc/s (−3 dB) at sensitivities from 50 mV/cm–50 V/cm.

Among the new cathode tubes this year are the **20th Century** (Stand 8) rectangular flat faced tubes: the single gun type S6RB/126 and the double gun type D6RB/710. **Electronic Tubes** (Stand 23) are demonstrating the effects of a new tube phosphor that has the property of trace storages for limited periods. Other tubes under development include the **GEC** (Stand 132) LD603 high efficiency post-deflexion acceleration tube and **Mullard's** (Stand 134) cold cathode glow discharge trigger tube for high peak current applications. New oscilloscope cameras are represented by **Langham Thompson's** (Stand 57) type 405 that supersedes the old series 400 and **Cossor's** (Stand 121) 1458 that allows for interchangeable lenses, including a fast F1·5 lens.

Instruments for measurement

With outputs varying from 50 μV/deg to 200 μV/deg. **Morgan Crucible's** (Stand 37) new thermocouples use graphite or silicon carbide/graphite. Mounted in a shallow pocket is the **Cambridge** (Stand 54) hot roll thermocouple for measuring the temperature of moving surfaces. **Langham Thompson** have an indicator unit that uses a 1 kc/s chopper amplifier and a 6 in Cirscale meter.

In the thermometer field is **Pullin's** (Stand 9) surface temperature instrument that will give a rapid and accurate reading up to 110°C; and **Cambridge's** battery operated multirange thermistor thermometer covering the range − 25° to 140°C. Temperature control of laboratory ovens and liquids is possible with the new **Electro Methods** (Stand 58) unit. It uses electrical contact thermometers in conjunction with the new type 213B transistor relay. Another unit, a stepless one, uses magnetic amplifiers and saturable reactors. **C.N.S. Instruments** (Stand 59) also have a saturable reactor type temperature controller for furnaces.

Suitable for both gauge and differential pressure measurements is the **Cambridge** transducer that provides ranges from 0–20 mmHg to 0–300 mmHg. Another transducer from **Langham Thompson,** the BP2, measures rapidly fluctuating and steady fluid or gaseous pressures as well as transients. Safe for excess pressures up to 10,000 lbf/in², **New Electronic** (Stand 62) have developed a single-ended variable inductance transducer for use with radioactive media. Under development by **Mullard** (Stand 134) is a pressure gauge to measure down to 10^{-9} torr in the low range and to 10^{-2} torr–10^{3} torr in the high pressure range.

The **UKAEA** (Stand 39) have among their exhibits a magnetic flow-measuring device for non-conducting fluids, slurries and dusts being developed at Winfrith Heath. Also in the experimental stage is **Lintronic's** (Stand 32) differential pressure pulsating flowmeter, sensitive to ½ in water gauge for full scale deflexion. Using three photo-transistors with light sources and a measuring pipette, is the **Langham Thompson** flow timer for transparent liquids.

Data processing

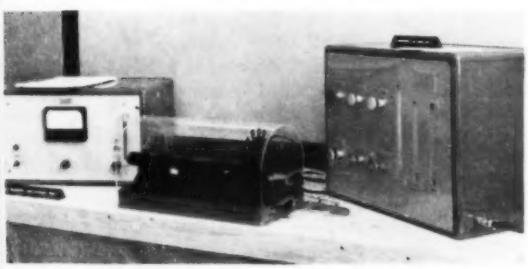
Also on the **UKAEA** stand is the data handling equipment developed at the AWRE for speeding up assessment of film records and presenting the data obtained in a form suitable for direct input to a computer. For thermonuclear research, with a particular application to a study of the fluctuations of the 'Sceptre' discharge, automatic methods were used by **AEI** (Stand 131) for data reduction. The system shown uses up to 12 gated two-decade scalers, a digital interrogator and a simple analogue-digital converter. **Venner** (Stand 19) have a complete data logging assembly for recording voltage, frequency, resistance or time interval from a number of sources. **Ericsson** (Stand 115) have available the new Dataflex printed board equipment for a wide range of applications.

Various ancillary equipment on show includes a transistorized A/D converter from **Standard Telephones** (Stand 112), three new transistorized digital frequency meters from **Racal** (Stand 16) and **International Computers'** (Stand 2) magnetic film digital store, shown with an experimental 2500 bit device arranged to store 50 words of 50 bits. Two new analogue computer units for teaching purposes have been developed, the **Servomex** (Stand 11) SS110 bench mounted simulator and the **Solartron** TY963. Also new from **Solartron** (Stand 111) is a high speed printer and a number of digital devices. **Elliott's** (Stand 125) exhibits include the 823 computer, a mechanical analogue, a solid state d.c. amplifier and a A/D converter.

Analysis

A new polarograph developed by the **UKAEA** at Woolwich and made by **Nash and Thompson** (Stand 40) offers facilities for the subtractive, comparative and derivative methods of two cells and single cell work. For the process control chemist is the **Baird and Tatlock** (Stand 136) 'Analmatic' process monitoring equipment made to suit different specifications. The **UKAEA** are showing a non-dispersive infra-red gas analyser and an automatic gas chromatographic analyser for the plant processing of volatile inorganic fluorides at elevated temperature and sub-atmospheric pressures.

GAS ANALYSER—UKAEA



STUDENTS' NOTEBOOK

GROUNDWORK—Computers

What are the uses of computers in nuclear design?

The size and complexity of nuclear design problems have greatly increased with the advent of atomic plant for commercial and advanced research purposes. This has led to a considerable degree of mechanization of the process of correlating or optimizing combinations of parameters for the particular design objective, so much so that computing aids have assumed an essential role in contemporary design fields.

Nuclear calculations of the basic properties of reactor lattices, control rod distribution, long term irradiation effects and the leading steady state design parameters of reactor cores are extensively programmed for digital machines, along with determination of optimum steam conditions and heat transfer properties, stresses in structures under various conditions of operation, to instance but a few of the more commonplace applications. Techniques have also been developed, but perhaps with limited success, for examining complex multi-dimensional spatial problems by physical analogue methods, but these have not yet appreciably developed as practical design tools.

In the field of transient analysis, however, the analogue computer has been extensively used in the solution of time-dependent integro-differential equations representing the dynamic state of the reactor following both operational changes and fault conditions. In principle the reactor dynamic properties are replaced by an electrical circuit having similar dynamic properties so that, by analogy, the variations of the electrical circuit (in response to appropriate stimuli) only vary from those of the reactor in respect of scale and time, both of which can be appropriately related with the original reactor equations.

A great deal of development has gone into the design of electrical and electronic computing elements which can be made to exhibit the mathematical properties of integration, differentiation, addition and subtraction or inversion, together with generation and multiplication of complex functions of variables. The computing accuracy may range between 2% and 0·01%, depending on both the degree of design sophistication employed and the type of problem under consideration, whilst the dynamic range may extend over several decades of output. Modern computing units employ printed circuits and are arranged to 'plug-in' to the system as required, whilst the standardization of power supplies and modular construction enable computers to be assembled in sizes ranging from a few score to many hundreds of operational computing units.

The principal advantages of the analogue computer, namely, the ease with which equation parameters may be varied and the simple manner in which complex feedback systems can be analysed, are now being increasingly challenged by the emergence of larger, faster, digital machines which, in some types of problems involving time-space transients, permit more detailed representations of problems than can conveniently be tackled by operational amplifier analogues. More recent developments combine the advantages of both digital and analogue techniques. It is likely however, that the use of electronic analogues in solving some classes of reactor problems will continue for some time to come.

BOOKLIST—Radioisotopes

Isotopes. J. L. Putman. Penguin Books. 1960. A popular presentation of all aspects of isotope applications. An elementary scientific background is desirable but not essential.

Radioactive Isotopes. W. J. Whitehouse and J. L. Putman. Oxford University Press. 1953. Another non-specialist treatise on the properties, production, measurement and use of radioactive isotopes. It assumes a general knowledge of elementary physics and of metals to 'O' level.

Radioisotope Laboratory Practice. R. A. Faires and B. H. Parks. Newnes, 2nd edition, 1960. A practical handbook for scientific workers using isotopes for the first time; applicable to a wide range of scientific problems.

Radioisotopes: a new tool for industry. S. Jefferson. Newnes, 2nd edition, 1960. Primarily for industrial managers and engineers, it is mainly descriptive and includes general applications together with an elementary background of radioactivity theory.

Radioisotopes for Industry. R. S. Rochlin and W. W. Schultz. Reinhold. 1959. A highly condensed treatment, mainly of principle and method for engineers and plant managers. Includes particular data on mechanical savings.

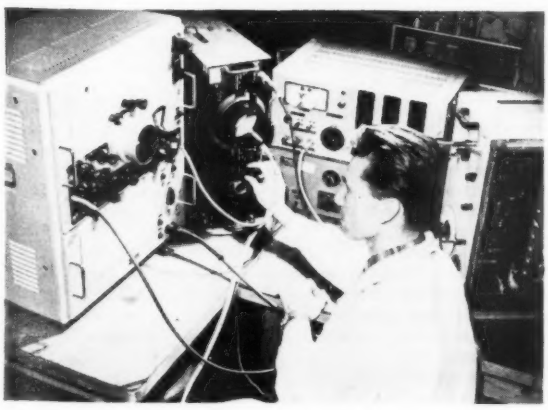
Radioisotopes in Biology and Agriculture. C. L. Comar. McGraw-Hill. 1955. Introduces basic principle and discusses detailed experimental practice, giving many diverse examples and references. The reader requires virtually no nuclear physics but a background of biochemistry and reaction kinetics is desirable.

Radioactive Tracers in Biology. M. D. Kamen. Academic Press. 1951. Intended for biologists with some knowledge of reaction kinetics, this is a thesis on techniques with special reference to the chemistry of biologically significant elements.

Atomic Radiation and Life. P. Alexander. Penguin Books. 1957. An introduction to radiobiology for the scientifically-minded layman.

Mechanical use of Radioisotopes. W. J. Bierwaltes *et al*. W. B. Saunders, Philadelphia. 1957. With its application to diagnosis and therapy, apart from discussing detailed clinical techniques, instruction is given on radioactivity, instruments, safety and management.

Therapeutic Uses of Radiation Radioisotopes. P. F. Hahn (editor). Wiley. 1956. A series of papers by specialists on the application of radioisotopes to the treatment of cancerous diseases.



Typical of the work conducted at the Czechoslovak Faculty of Technical and Nuclear Physics in Prague's Charles University, this pulse generator, constructed by the student himself, is being tested for quality control. The Faculty, started in 1956, has a student roll of 600 divided into specialist groups for nuclear physics, nuclear engineering and nuclear chemistry.

UK COURSES

Hendon Technical College, Middlesex Uses and safe handling of radioactive substances. Thursday evenings, February 23–May 18. Fee: £1.

Bristol College of Technology Radiological Health Hazards and Health Protection. Courses for medical officers, factory inspectors and engineers. March 13–24. Fee: £5 5s. Teaching Radiochemistry and Nuclear Physics in Secondary Schools. May 23–26. Fee: £2 2s.

Borough Polytechnic, London Metallurgy of Rarer Metals. Six lectures on Tuesday evenings commencing February 7. Fee. 10s. Nuclear Power Technology. 13 lectures on Thursday evenings commencing January 12. Fee: £2.

Points from Papers

reports, meetings, conferences

VAPOUR DEPOSITION

Encapsulation of fuel elements is becoming an established method of maintaining mechanical integrity and containing fission products. Uniform, dense, nonporous coatings on individual fuel particles have been obtained by the vapour deposition of niobium, molybdenum, tungsten, chromium, carbon and niobium-vanadium alloys in a fluidized bed of UO_2 particles. Work at Battelle Memorial Institute has been mainly on niobium using hydrogen reduction of niobium pentachloride vapour. It is reported that the most serious problem was maintenance of bed fluidity and avoidance of agglomeration. This has now been overcome and routine operation can be carried out with a loss due to agglomeration of about 1%.

Fluidized-bed coating of UO_2 powder with niobium and other elements. John M. Blocher, Jr *et al.* Battelle Memorial Institute. **Report BMI 1440.** 52 pp. Available from OTS $1·50 or depository library.

HIGH ENERGY SPECTRA

An IBM 709 program is described for obtaining high energy spectra in a specified configuration. The system contains a number of fissile and non-fissile materials arranged as concentric cylinders of infinite length. These are surrounded by an outer material with a square or rectangular boundary. A current version of the program is available as a self-loading binary tape which contains, in addition, all the nuclear data available at present. The complete program occupies about 4500 words of core storage and nearly all the operations are performed using the floating point technique.

A monte carlo program for calculating high energy spectra in cylindrical geometry on the IBM 709 computer. S. Francescon. AEE Winfrith. **Report AEEW R 45.** 20 pp. Available from HMSO 3*s* 6*d*.

PARTICLE SIZE ANALYSER

A method of particle size determination and distribution based on measurements of the relative spread in repeated determinations of scattered radiation intensity as a function of viewing aperture diameter is described. The experimental work reported includes; evaluation of suitable beta sources, investigation of the optimum geometry required for these sources and data proving the feasibility of the principle.

The development of a beta-ray particle size analyser. Seymour Z. Lewin, Jane Connor Sheridan and Eric J. Hewitt. Evans Research and Development Corp. **Report NYO 2655.** 42 pp. Available from OTS $1·25 or depository library.

COATED FUEL PARTICLES

This paper reports an information meeting on work carried out at the Battelle Memorial Institute. Three main topics were covered; coated-particle fabrication, fuel-element fabrication and in-pile testing. Interest at Battelle is related to their fuel element evaluation programme for the Sanderson and Porter pebble bed reactor concept. The main type studied has been alumina-coated fully-enriched UO_2 manufactured by the fluidized-bed technique. This has shown excellent fission product retention at 30,000 MWd/t burnup in the BRR. Less extensive work on carbon coated UC_2 is also reported.

Progress on ceramic-coated fuel particles at Battelle. AEC information meeting. **Report BMI 1468.** 31 pp. Available from OTS $0·75 or depository library.

NIOBIUM ALLOYS

Niobium, already an attractive metal from the point of view of mechanical strength, thermal conductivity and corrosion resistance to sodium, can be markedly strengthened by alloying. The work reported here indicates that both chromium and zirconium are potent strengtheners of niobium. Limited investigations have shown that strong and reasonably ductile welds can be produced by both arc and spot welding. Improved fabrication techniques are also reported.

Development of high-strength niobium-alloys for elevated temperature applications. J. A. De Mastry, F. R. Shober and R. F. Dickerson. Battelle Memorial Institute. **Report BMI-1417.** 22 pp. Available from OTS $0·75 or depository library.

FUEL PROCESSING

This report is about the work, briefly mentioned at Geneva 1958, on the behaviour of plutonium, uranium and some fission products in a system where uranium-plutonium alloy is melted under calcium. Rare earth and alkaline earth metals are extracted into the calcium while the plutonium, uranium and noble fission products remain in the fuel alloy phase. The authors conclude that molten calcium can be used for processing metallic fuels from fast reactors provided the fuel melts well below 1000°C and a suitable containment can be found. The process does not compare favourably with that of oxide slagging. There is an appendix on the determination of tantalum, lanthanum and barium in uranium by tracer technique and spectroscopy.

The use of molten calcium in the processing of metallic fast reactor fuels. I. L. Jenkins, N. J. Keen, D. Lawson and J. L. Woodhead. AERE Harwell. **Report AERE R 2949.** 21 pp. Available from HMSO.

FUEL CELLS

A 160 pp report prepared by graduates of the Harvard Business School for Fuel Cell Research Associates examines several fuel cells being considered for commercial application. They conclude from their economic and technical analysis that 'the fuel cell is definitely not in the class of exotic power sources and should soon play a major role in industry'.

The report, which is extremely thorough, concludes that the most practical cell examined was Union Carbide's hydrogen-oxygen cell.

Fuel cells. Available from Fuel Cell Research Associates, P.O. Box 157, Cambridge, Mass., USA, $18·75.

LOW ENERGY BETA PROBE

Present probe designs used for measuring surface contamination are unsatisfactory for detecting low energy beta emitters. A new design of scintillation counter, based on a prototype by R. E. Owen, uses a thinly deposited anthracene screen. The efficiency claimed is 14% for C-14 and 28% for Sr-90. The detecting area is over a 5 in dia. circle and the design can be used with most standard ratemeters.

A low energy beta probe. K. E. G. Perry and R. A. Bishop. AERE Harwell. **Report AERE M 771.** 12 pp. Available from HMSO 3*s*.

WIGNER RELEASE

Wigner stored energy in irradiated graphite may under certain conditions be released in the form of a thermal wave. This work describes calculations made to determine what amount of uniform cooling is needed to inhibit the propagation of the thermal wave. On the basis of a relaxation time model for graphite heat release kinetics the authors conclude that a time constant for cooling of about two hours is sufficient to prevent propagation through a typical graphite at 100°C.

Propagation of thermal waves through graphite with uniform cooling. A. J. E. Foreman and A. R. Curtis. AERE Harwell. **Report AERE R 3500.** 11 pp. Available from HMSO 2*s* 6*d*.

New Reports

The recovery of uranium from reduction residues by semicontinuous ion exchange. N. J. Setter, J. M. Googin and G. B. Marrow. Union Carbide Nuclear Co. **Report Y-1257.** 21 pp. Available from OTS $0·75 or depository library.

Space power reactor optimization. K. E. Buck and D. L. Cochran. Aerojet-General Nucleonics. 4 pp. For copies apply to the authors.

Radioactivation analysis — a bibliography, first supplement. Compiled by D. Gibbons, D. Mapper, R. J. Millett and H. Simpson. AERE Harwell. **Report AERE I/R2208 (Supplement 1).** 34 pp. Available from HMSO 4*s* 6*d*.

The spectrographic determination of beryllium in atmospheric dusts. J. C. Cotterill. AERE Harwell. **Report AERE AM 56.** 12 pp. Available from HMSO 2*s* 6*d*.

The preparation and testing of iodine-132 column generators. J. Robson. AERE Harwell. **Report AERE M 749.** 17 pp. Available from HMSO 3*s*.

Capacity, control and 'TBP steam stripping'. Trials on a small evaporator. B. T. Bell and S. S. Grimley. AERE Harwell. **Report AERE R 3508.** 23 pp. Available from HMSO 4*s*.

Proceedings of the organic cooled reactor forum, 1960. Published by Atomics International.

Small reactors for Northern Canada. Atomic Energy of Canada Ltd. **Report AECL 1045.** 31 pp. Available from Scientific Document Distribution Office, AECL, Chalk River, Ontario, Canada, $1·50.

AMERICAN NUCLEAR SOCIETY

Some points from the papers presented to the American Nuclear Society meeting held in San Francisco last December. A full report of the Eighth Hot Laboratory and Equipment Conference, held in conjunction with the meeting, is given on pp 72–74.

TEMPERATURE PROBES

An important step towards reducing hot-channel factors is the direct measurement of individual fuel-channel coolant temperatures. The method outlined replaces thermocouples with pneumatic temperature probes. It is claimed that the initial and operating costs are less than for the equivalent, replaceable thermocouple system when integrated with the burst fuel element system, and that the system can be maintained to operate at a desired accuracy throughout the life of a gas-cooled plant. The system has been designed for use in the EGCR. It is expected that pneumatic probes will become of increasing importance as gas outlet temperatures increase beyond the useful range of thermocouples.

The use of pneumatic probes in gas-cooled reactors. L. L. Kintner, D. A. Lampe (Allis-Chalmers Mfg. Co.) and A. Armstrong (Marquardt Aircraft Corp.)

PLUTONIUM RELEASE INCIDENT

A short report of a non-nuclear explosion involving an evaporator, which occurred in a shielded cell in the Radiochemical Processing Pilot Plant at ORNL in November 1959. The explosion was due to inadvertant nitration of a proprietary decontaminant which deflegrated. The physical damage was slight and no one was hurt either by the explosion or the radioactivity release. The report describes the decontamination carried out and the safeguards now employed to prevent a similar occurrence. Full details of the incident will be given in USAEC report ORNL 2982 which will be available soon.

Plutonium release incident at Oak Ridge National Laboratory. J. C. Bresee and L. J. King. ORNL.

MERCURY COOLED REACTORS

There were two basic objectives of the programme outlined in this paper. The first, establishing the feasibility of a fast breeder reactor cooled with boiling mercury, and secondly the evaluation of the long range potential of such a reactor plant for producing economic power. Initial work on the programme was reported in the AEC research and development report ATL-A-102 (available from OTS). A final report covering the current work will be available later this year.

Extensive work has been carried out on core design parametric studies leading to the conceptual design of a complete power plant. Background information from the experience gained in conventional power plants using the so called mercury topping cycle and on fast breeder technology developed for the EBR and the Enrico Fermi programme. The attractiveness of mercury as a thermodynamic fluid is because of its good heat transfer properties, it is not subject to thermal or radiation decomposition, it is chemically inert, has a low vapour pressure at high temperatures and the vapour can be used directly in a turbine.

The initial studies have been limited to a plant using an indirect mercury cycle and using U-10% Mo fuel. The plant will produce 100 MWe and this figure allows direct comparison to be made with the fuel cycle and capital costs of sodium cooled reactors. The author says that the study shows that the MCBR is technically a feasible reactor showing a long range economic potential.

Evaluation of mercury cooled fast breeder reactors. D. W. Battles. Advanced Technology Laboratories. **Report ATL-505.**

CLADDING DEFORMATION

An experimental programme to determine whether the thin cladding, of interest in superheat reactors, will undergo plastic strain cycling as a result of UO_2 thermal expansion or cracking during irradiation was presented to the meeting. It discussed the results reported in the three progress reports on nuclear superheat, GEAP-3468, GEAP-3538 and GEAP-3581. The results reported are for a series of experiments with different clad thicknesses and diametral clearances. One of the most interesting results showed that cladding had well defined ridges over each pellet-to-pellet interface. Further experiments showed that these ridges appear to depend on the initial gap spacing rather than the high heat flux. The ridges have been observed on each capsule with an initial 0·009 in gap but only faintly or not at all on those with smaller gaps. Further work is being directed towards establishing whether growth would be cyclic with changes in reactor power.

Deformation of thin cladding by thermal expansion and/or cracking of UO_2. M. F. Lyons. Atomic Power Equipment Department. General Electric Company.

XENON INSTABILITY

A model is presented for extending the investigation of the fundamental mode xenon instability to include temperature effects. The paper shows that for positive values of the overall flux coefficient the linear stability curves for reactor reactivity against the ratio of temperature reactivity defect to xenon reactivity defect are S-shaped. When the temperature reactivity defect is greater than the xenon reactivity defect, the reactor is absolutely stable against xenon oscillation. The general adequacy of the model has been checked by using the 'Newton's Law of Cooling' model for temperature effects and by the addition of delayed neutron emitter equations.

The effect of temperature on xenon instability. J. Chernick, G. Lellouche and W. Wollman. Brookhaven National Laboratory.

PRTR FUEL SCHEDULING

Information obtained from burnup and yield equations programmed on a differential digital analyser have been integrated with procurement scheduling, fuel fabrication requirements and chemical reprocessing batch schedules to provide an overall PRTR plutonium fuel schedule. The report says that a steady state cycle will be expedited by introducing about 35 kg of nominal 20 wt-% of Pu-240 into the reactor feed plutonium inventory.

Plutonium recycle reactor fuel scheduling. J. G. Bradley. General Electric Company.

THERMIONIC REACTOR SYSTEMS

Data required for the incorporation of thermionic cells into reactor systems is already available. This paper describes the fundamentals involved in converting nuclear heat into electricity using such cells and considers three concepts for their application; in-pile; pile-surface; and out-of-pile. The report also details likely applications for these systems in space, marine and central-station plants.

Thermionic reactor systems. R. C. Howard. General Atomic. **Report GA-1842.**

AUTOMATIC POWER STATION

A system which will produce 1 MW of electricity for one year unattended is required for field use in about four years time. The authors of this paper have examined the PWR concept and conclude that a reliable, simplified system can be developed in the time. They say that four years does not allow development of new concepts and technology and that they chose the PWR because it appears readily adaptable to simplification and there is favourable operating experience. Control requirements are satisfied with a system based on the inherent self-regulating characteristics of a highly enriched PWR. Water treatment would not be necessary if the plant were hermetically sealed.

The feasibility of an unattended nuclear power plant. M. W. Rosenthal *et al.* ORNL. **Report ORNL-2985.** 64 pp. Available from OTS $1·75 or depository library.

FISSION GAS COLLECTION

The amount of fission gases in ceramic fuels affects the optimization of the cladding design. To determine accurately the quantity of fission gases, a vacuum system has been devised at Vallecitos which contains equipment for puncturing fuel elements of almost any physical configuration and for heating fuel specimens in any controlled atmosphere. It is claimed that for these high temperature gas evolution studies, the error of reproducibility is 5%.

A fission gas collection system. R. E. Womack. Atomic Power Equipment Dept, General Electric. **Report GEAP-3577.** 10 pp. Available from General Electric, Vallecitos.

Radiography for nuclear power

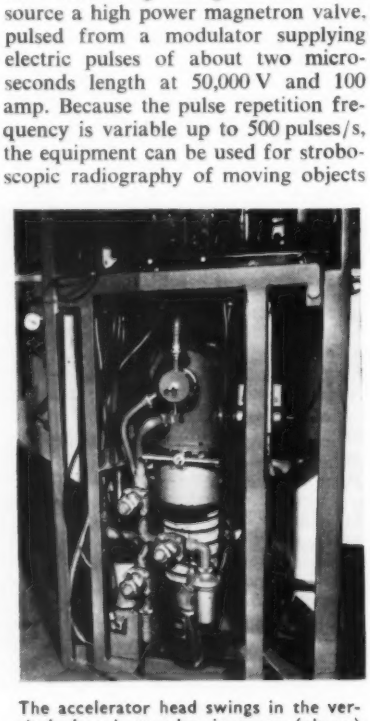
world's first mobile accelerator

THE FIRST completely mobile linear accelerator in the world has recently been delivered to the UK Atomic Energy Authority. Designed by Mullard under contract to the AEA, this 4·3 MeV, 2 ton unit will permit the welds in the four-inch thick steel walls of pressure vessels to be radiographed on site with the minimum disturbance to constructional work. It will be used for the first time at Trawsfynydd.

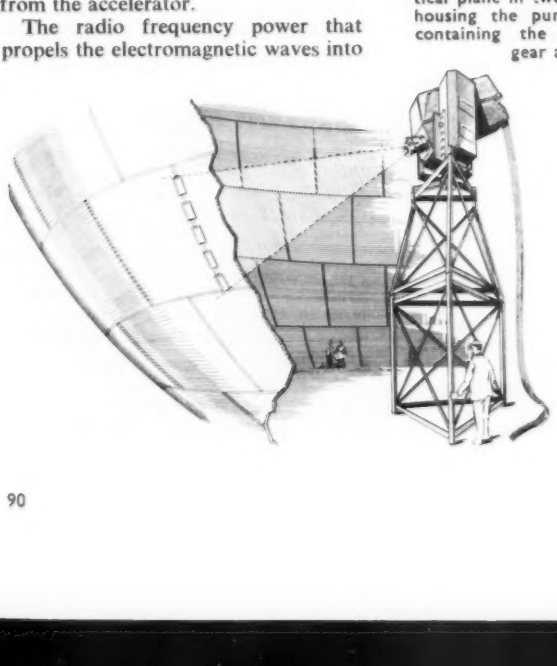
Incorporating many of the standard components employed in Mullard's standard range of 4·3 MeV accelerators, the new equipment has been engineered into a robust self-contained unit, measuring approximately 8 ft 9 in long by 4 ft 9 in wide by 5 ft high. It can be rotated about both horizontal and vertical axes for rapid, accurate alignment on to the specimen; it may also be mounted on a tower, or suspended from suitable lifting tackle.

A novel feature is the incorporation of the entire vacuum and cooling systems in the accelerator unit, thereby eliminating the need for lengthy hose connexions. The control cabin, which houses the ancillary electrical and control equipment, is a transportable weatherproof structure of fibreglass which may be sited up to 250 ft away from the accelerator.

The radio frequency power that propels the electromagnetic waves into the accelerating waveguide has as its source a high power magnetron valve, pulsed from a modulator supplying electric pulses of about two microseconds length at 50,000 V and 100 amp. Because the pulse repetition frequency is variable up to 500 pulses/s, the equipment can be used for stroboscopic radiography of moving objects by relating the frequencies to the periodicity of movement.



The accelerator head swings in the vertical plane in two bearings, one (above) housing the pumping gear, the other containing the power driven tilting gear and radiator



The machine is positioned at the centre of the pressure vessel (left), and to assist alignment of the beam, the field area is illuminated

The control cabin and motor alternator (right) provide a stabilized power supply

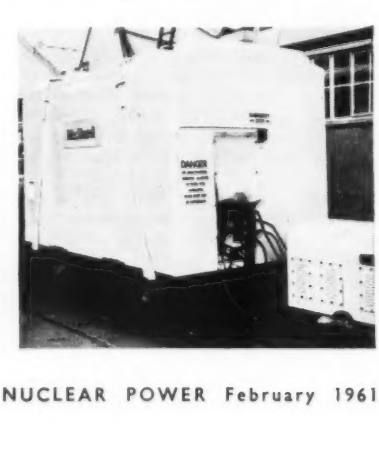
★ 280

This Mullard 4 MeV linear accelerator can be mounted on a simple tower or suspended from suitable tackle. Rotation about both horizontal and vertical axes is possible

In addition to the pulse modulator, the various ancillary equipment provided includes a p.r.f. generator, electron beam lens power supplies, control and monitoring units and general power supplies.

The maximum intensity of X-radiation is over 600 roentgens/min measured in air at a distance of 1 m from the target. This radiation is collimated by a heavy metal cone to a diameter of 30 cm, and field defining diaphragms enable the field to be adjusted to any size from 30 by 20 cm down to 30 by 5 cm at 1 m from the target. The head can be rotated for field alignment, and automatic termination facilities by time or radiation dose are incorporated.

The time required to obtain a radiograph through 4 in of steel with the accelerator 1 m from the surface of the object is as little as 4 s; an 8 in thickness can be radiographed in 42 s; and 12 in in less than 9 min.



High speed radiography
8 MeV linear accelerator

Another linear accelerator, with even greater radiographic intensity, is being built by High Voltage for A. O. Smith's Atomic and Process Equipment division. Using an operating head 11 ft long and 30 inches diameter, with a 12 in radiation aperture, this new 8 MeV 'Linac' will produce 6000 roentgens/min.

The equipment provides a choice of focal spot sizes of one millimeter and five millimeters, with respective outputs of 1500 and 6000 roentgens/min. At full power and at a distance of 9 ft, the 5 millimetre focal spot source will X-ray an 11 in thickness of steel in about 1 min, or 16 in of steel in about 18 min. The 1 millimetre focal spot source, providing greater clarity or resolution, will radiograph 8 in of steel in about 1 min, or 14 in of steel in about 30 min.

Unlike the new Mullard accelerator, the 'Linac' is not intended for on-site application. It will be housed in a special building with 6 foot thick concrete walls. The room that houses the operating head will be 40 by 80 ft, large enough to allow the passage of railroad flat cars that will carry the material to be radiographed.

In operation, the head will be suspended from an overhead crane to permit raising it from floor level to a height of 16 ft. It can be tilted to point its beam vertically downwards, or it can be rotated to 45° upwards. For safety precautions, the arc of the operating head is limited so that it can never be aimed at the main entrances of the room. In addition, interlocks prevent operation if any of the lead-shielded doors are left open.

★ 281

UO_2 bonding
low-cost fuel elements

A method for fabricating low cost stainless steel clad UO_2 fuel elements by the gas-pressure-bonding technique has been investigated at the Battelle Memorial Institute. Both the densification of the oxide and its cladding in a single bonding operation was achieved. The programme included rod, flat-plate and tubular designs.

Initial studies covered the characterization of the oxides and their cold-compaction behaviour; cold-pressing was established at 10 to 55 tons/in², and green densities of up to 86% of theoretical were achieved. It was also found advantageous to employ mixtures of the oxides to attain high density cold-compacted cores which were 'active' during subsequent pressure bonding. Bonding conditions of 3 h at 2100°F and 10,000 lbf/in² produced optimum tensile properties in the stainless steel bonds and also permitted attainment of high final oxide densities (Table 1).

Determinations revealed that those uranium dioxides with excess oxygen tended to return to stoichiometry during the bonding operation. Permeability and thermal conductivity determinations on selected specimens yielded values consistent with pressed and sintered oxides of equivalent densities. Mixtures of the ceramic and fused grades, containing from 30–60 w/o ceramic oxides, demonstrated the most promise.

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TABLE 1 *Densities of pressure-bonded uranium dioxide*

DESCRIPTION OF OXIDE	RANGE OF INITIAL DENSITY, % of theoretical		RANGE OF BONDED DENSITIES[a], % of theoretical	STRUCTURE[b]
	Pressed 40–50 tons/in²	Tamp packed		
Mallinckrodt ceramic	54·8–58·3	—	96·7–98·5	High density with little apparent porosity
	—	19·0–20·0	98·5–99·5	
Mallinckrodt and Numec high fired	72·7–76·1	—	90·3–95·8	Little grain growth, particles not well bonded
Mallinckrodt special dense	75·6–80·3	—	83·1–93·1	Oxide particles remained porous, point bonding
	—	54·9–63·4	85·7–89·6	
Spencer fused	77·2–85	—	82·5–94·9	Point bonding, budging effect in structure
	—	53·8–69·4	82·5–88·9	
Fused and ceramic mixture				
25% ceramic	72·0–83·5	—	92·2–96·7	Occasional budging of particles
40% ceramic	74·5	—	97·8	Low porosity well bonded
50% ceramic	67·0–72·0	—	99·0–99·5	,,
75% ceramic	63·0–67·1	—	99·0–99·5	,,
Fused and high-fired mixture				
25% high fired	78·5–86·8	—	88·9	Little or no bonding
High-fired and ceramic mixture				
25% ceramic	68·5–71·4	—	92·9–95·0	Well bonded, apparent high porosity

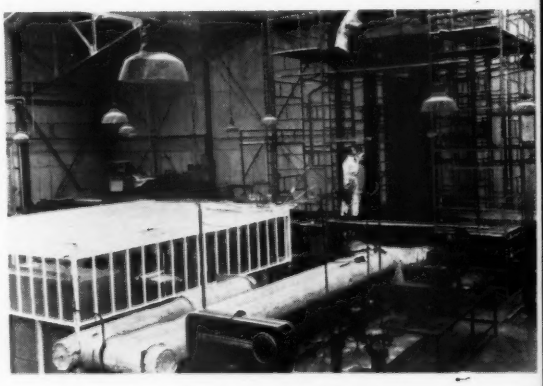
(*a*) Samples bonded at 2100 to 2300°F for 3 h at 10,000 lbf/in². (*b*) Comments based on metallographic observation.

Research at Argonne
activities reviewed

Argonne National Laboratory has just completed its fourteenth year of activity. Operated by the Chicago University, with its complex of over 100 buildings and a total staff of 4000, the establishment has made significant contributions to nuclear energy developments.

The major event for 1960 was the commencement of the 12 GeV proton synchrotron project, a £M15 facility that will be used not only by American scientists, but also by those from other countries (see *Nuclear Power*, August '60, p. 97). Another major tool for basic research, commissioned in 1960, is the double-focusing mass spectrometer of 100 in radius.

On the reactor side, and aimed at more efficient power generation, is the building of the fifth in a series of boiling water reactor experiments, Borax V, incorporating a nuclear



WORKING FOR HECTOR Fairey Engineering, who have already designed and constructed rig and loop assemblies for the UKAEA's DIDO, PLUTO and BEPO, are the main contractors for Winfrith Heath's HECTOR, a zero energy experimental reactor scheduled to go critical during 1962 (see 'Nuclear Power', December 1960, p. 98). The degree of temperature control required for this particular design is very close, and the temperature stability test rig shown is a graphite stack contained within the vessel surrounded by scaffolding, and it is being used to simulate HECTOR's core

★ 283

superheater, and scheduled for completion by Spring 1961. The Experimental Breeder Reactor II will also be completed about the same time. By mid-1961, the Juggernaut (see this issue, p. 81) should be operating and a programme of work is scheduled for the development of nuclear instruments and research work associated with analytical chemistry and electronics. Started, but scheduled for 1962, is a fuel reprocessing facility that is directed towards reducing the existing high processing costs.

★ 284

Extending the supergrid

Dungeness link

In continuance of the 275 kV supergrid into South Eastern England, and forming part of the plan for closing the ring around London, the two 615 ft towers for the Thames crossing at West Thurrock have been completed. The new line, of which the crossing forms a part, will continue via Canterbury to Lydd with connexions to the cross-channel cable link and to the nuclear power station at Dungeness.

Designed by Blaw Knox, with construction by BICC, using Sykes equipment for lifting, the towers which are made from high-tensile steel will have to support a transmission line span of 4500 ft and a minimum clearance of 250 ft above mean high water.

★ 285

PERSONAL RADIATION MONITOR A new radiation protection instrument has been developed at Oak Ridge National Laboratory about the size of a fountain pen, that weighs only 3½ oz, and gives an immediate warning sound and a flashing signal in the presence of a gamma radiation field. Proportional indication of radiation intensity is obtained over a range from natural background to 200 roentgens per hour. The normal range extends from background to one roentgen an hour. By inverting the device, the range is automatically increased to 200. The instrument uses a miniature Geiger counter and a tiny hearing aid earphone coupled to a resonant air column as the warning tone source

★ 286

BOILERS FOR TRAWSFYNYDD The twelve 350-ton boilers are fabricated on site from completed single strake sections. Using Yates manipulative equipment and 28 ft high welding travelling columns with retractable beams, these single sections are first welded together on five sets of rotators to form double strakes, after which they are lifted on to either of two final assembly travelling rotator sets for the final welding operation. Internal gear and pinion power unit drives for the rotators were incorporated in each set to give greater clearance for the thermal sleeves and the superstructure ★ 287

Isotopes for mining

NCB steering device

Radioisotopes are being used in Britain as an aid to underground coal production. Still in the experimental stage is a nucleonic steering device, developed at the Isleworth Mining Research Establishment, that will prevent power-loading machines from cutting into the uneven rock floor of the seam as they move along the coal face.

The radioisotope, mounted on the machine near the floor, emits low energy gamma-rays. The intensity of scattering of these rays, measured on a meter in view of the operator, will show the distance between the lower coal cutters and the floor by indicating variations in the thickness of a 'skin' of coal left by the machine. The operator will thus be able to prevent the machine from cutting into the rock floor, despite slight undulations in the seam. On its proving tests at the New Lount Colliery, Leicestershire, but as yet only hand steered, its use has halved the dirt content.

A subsequent development will be to link the information from the nucleonic device to electro-hydraulic valves operating the machine's steering system, thereby giving 100% completely accurate automatic and vertical steering control. ★ 288

IN BRIEF

Heavy water monitoring AECL have designed an instrument for heavy-water analysis by automatically measuring infra-red absorption at three or more wavelengths. Changes of 10 p.p.m. in the light-water content of heavy water can be detected.

★ 289

New radiation laboratory Employing cobalt-60, caesium-137, and spent fuel elements, and with a total radiation of some two million curies, the Brookhaven National Laboratory has commenced building a new laboratory for process radiation development.

★ 290

Pumping corrosives A rotary pump, suitable for operation in hydrofluoric acid has been developed at the UKAEA, Capenhurst. The pump's main feature is a long hollow shaft with bearings self-lubricated by an enclosed oil circuit.

★ 291

Radiochemicals aid medicine The UKAEA at Amersham are growing Chlorella, or green pond slime, under closely-controlled sterile conditions in an atmosphere of radioactive CO_2. This is to ensure uniform saturation of all atoms, so necessary in its use as a tracer for research into heart diseases and in antibiotics. Separation of the micro-organisms is done by ultrasonics, centrifuge, freeze-drying and paper chromatography.

★ 292

Control rod generators Bruce Peebles are making the l.f. generators for Trawsfynydd's control and rod drive. The system, essentially static, generates at low level a very low frequency 3-phase waveform, that is amplified up to kW level by magnetic amplifiers. A first sector cubicle, capable of driving up to 5 rod motors, is about to undergo tests.

★ 293

Liquid level monitor Making use of moiré fringe light diffraction patterns, an automatic burette monitor has been devised at the UK AERE that determines the height of a liquid to within 0·01 in.

★ 294

Radiation monitor for Germany The first to operate on the continent of Europe, Nuclear Enterprises human body monitor (see *Nuclear Power*, August, p. 103) has been installed at the Karlsruhe Reactor Centre. Associated with it is the largest electronics unit of its kind. Housed in an 11 ft long console desk, it includes five non-overloading linear pulse amplifiers, three single-channel pulse height analysers, and an eight-channel scaler.

★ 295

Magnesium oxide fibres Resembling fibre glass, Semi-Elements have produced on a laboratory scale, MgO fibres of a few microns in thickness. Because of its interesting potentials, investigations into commercial production feasibility are being carried out. As a fabric it would withstand temperatures $> 2600°C$; suitably doped it could be used to form filaments that would light up in the open air.

★ 296

★ *For further information on any item, circle the appropriate number on the reply card facing page 114.*

IAEA/ENEA AGREEMENT The protocol regarding entry into force of the agreement for collaboration between the European Nuclear Energy Agency and the International Atomic Energy Agency is signed by (left to right) M. Pierre Huet, Director, ENEA, Prof. Leandre Nicolaidis, chairman of the ENEA Steering Committee, and the Hon. W. Sterling Cole, Director General, IAEA

People

by John Radford

RECENT expansion of Ekco Electronics activities in the Southend area has led to some reorganization of individual responsibilities. Chief of these is the appointment of **Mr P. J. Harvey,** formerly chief electronics engineer, as manager of the Nucleonics and Industrial Division. In his new post, he will be responsible for research and development covering nucleonic and physical

P. J. HARVEY
Industrial manager

A. G. WRAY
Marconi appointment

instrumentation and control. The division is engaged in the application of these techniques in research and medicine, industry and reactor instrumentation.

Among the four new engineering appointments announced by Marconi Instruments Ltd is that of **Mr A. G. Wray** as Deputy Chief Engineer. For the past four years, he has been in charge of the company's Advanced Development Group, responsible for the design and development of atomic power instrumentation and multi-channel microwave test equipment. Mr Wray joined the company in 1944 and was appointed company physicist in 1952. Other Marconi appointments are that of **Dr R. L. Gilbert** as advanced product engineering manager: and **Mr A. Haviland** and **Mr D. R. Willis** as proprietary engineering managers responsible for the design and development of groups of products.

Congratulations to **Sir John Cockcroft** on his winning the 1961 Atoms for Peace Award. Sir John, a 1951 Nobel Prize Winner, will receive the award on April 6 at the Massachusetts Institute of Technology. The award was established as a memorial to **Henry Ford** and his son, Edsel, in response to President Eisenhower's 1955 Geneva appeal for international efforts to develop nuclear energy for peace.

Promotion plans for 1961 were discussed by **Mr Richard Foxwell,** managing director and **Mr Gordon Bell,** general sales manager of Wayne Kerr Laboratories during their recent visit to the United States. Talks were held with their American company in Philadelphia, with particular emphasis on the introduction of their Transfer Function Computer to the US market at the Institution of Radio Engineers Show, New York, in March. The American market is, of course, an important one for Wayne Kerr as total exports account for more than 40% of their production of instruments in the UK.

With 27 years as a member of the Institution of Works Managers behind him, **Mr Alan Meredyth Hudson Davies,** managing director of Fibreglass Ltd, was elected chairman of the Institution for that body's 30th year. Mr Davies was honoured with a Fellowship of the Institution in 1945 in recognition of his outstanding contribution to industry. Aged 59, Mr Davies is a member of the Council of the University of Liverpool, a member of the Grand Council of the Federation of British Industries and a Governor of Fircroft College for Adult Education.

A noted mathematician and an authority on nuclear reactor theory, **Dr J. Ernest Wilkins Jr** has joined General Dynamics Corporation's General Atomic Division.

HUDSON DAVIES
new chairman

J. E. WILKINS
joins
General Dynamics

His post is assistant chairman of the Theoretical Physics Department at the John Jay Hopkins Laboratory for Pure and Applied Science. Dr Wilkins was previously manager of research and development, Nuclear Development Corporation of America. A major part of his work has been in the area of the penetration of neutrons and gamma rays through matter.

Mr A. R. O. Williams, a managing director of Consolidated Gold Fields of South Africa Ltd, has been elected president of the Institution of Mining and Metallurgy for 1961–62.

Mr Frederick Baillie, who joined the Cambridge Instrument Company as production manager in August, will be responsible for production planning at the company's three UK factories.

Mr Milton F. Pravda has joined the Martin Company's Nuclear Division as chief of system design. He was former manager of reactor design for the USAEC's Natural Circulation Reactor project.

Mr J. H. Price has been appointed general manager of Expandite (Australia) Pty Ltd.

New Product Survey

EQUIPMENT · INSTRUMENTS · MATERIALS

REMOTE HANDLING

new manipulators

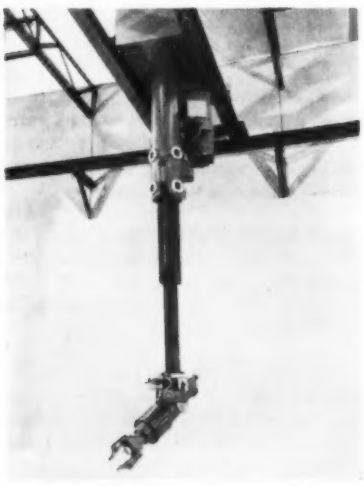
With the introduction of three new remote handling manipulators, Nuclear Equipment's range of equipment now extends from the smaller hand-operated manipulators capable of carrying out a full variety of movements on loads up to about 10 lb, to the largest of the powered mechanical arms capable of a direct lift on loads up to 5000 lb.

The NE9, a modified version of the NE8 manipulator, meets the demand for handling weights in the 8–30 lb range, and its typical uses are the lifting and handling of fuel elements, and the manipulation of valves, clamps and specialized power hand tools.

The Model 100 powered mechanical arm of General Mills design, has a load capacity of 40 lb for all manipulations, and of 200 lb for direct lift with hook. Three motions are provided: grip, wrist rotation and elbow pivot. Brakes or irreversible drives are used in each motion to ensure against creeping under load, and to obtain fail-safe operation. Limit switches control the forearm movement through an arc of approximately 270° in the vertical plane. The maximum upper arm rotation is through 2½ revolutions, whilst wrist rotation is fully continuous in either direction.

The Model 150, also from General Mills, has been specifically designed for alpha-gamma handling in a confined space. It can be mounted on a conventional overhead bridge or boom, or it can be suspended from the ceiling of a dry box. Six motions are provided: continuous rotation of the entire arm at 3 rev/min; a full 360° movement about the shoulder; an arc of 300° in the plane of the upper arm; an arc of 180° in the plane of the forearm; a continuous rotation in either direction of the wrist; and a grip that opens 2½ in. Load carrying capacity is up to 40 lb.

★ 208



The Model GM100 powered mechanical arm gives complete cell coverage, both lengthwise and across, and a master rotary selector switch gives a choice of four speeds for each movement

FEED WATER ANALYSER

automatic measurement

Modern high-pressure boilers operating above 482°C must have the very minimum of silica concentration in the feedwater. The EIL silica analyser, model 58A, manufactured under licence by Electronic Instruments, solves the problem by providing a completely automatic means of measuring the concentration of silica in water.

It is essentially a colorimeter—a measured sample of water is taken automatically, a fixed volume of molybdate solution is added followed by the reducing agent. A blue shade develops which is compared photoelectrically with a perspex blank. The differential output of the photocells feeds a transistor amplifier giving an output of 1 mA into a resistance of 1500 ohms for full-scale deflexion. The output drives a suitable recorder; the whole sequence is automatic and is controlled by a mechanical programme timer.

★ 209

SOIL DENSITY METER

uses radioactive source

To assist in the control of soil compaction, a meter that determines both density and moisture content to an accuracy of 1·5% has been developed by Soil Mechanics, in association with Dynatron.

The density system comprises a caesium contained in the end of a stainless steel probe, and a Geiger-Muller tube. The moisture system consists of a radium beryllium source, a BF3 proportional counter, and a transistorized e.h.t. and pre-amplifier assembly. The sources are shielded by lead and sintered tungsten and a locking device fitted to the probe prevents accidental exposure.

The scaling unit circuit comprises five counting display tubes fed by transistors that enable a total of 10^5 counts to be registered. The unit includes a stabilized voltage for the G.M. tube, a test pulse generator and a built-in timer. Power is provided by a compact rechargeable battery enabling ten hours' continuous operation.

For density measurement, a gamma source housed in a probe penetrates the ground to a fixed depth. For moisture content, a fast neutron source is placed on the ground surface and the intensity of the slow neutrons scattered back from the soil is detected

★ 210

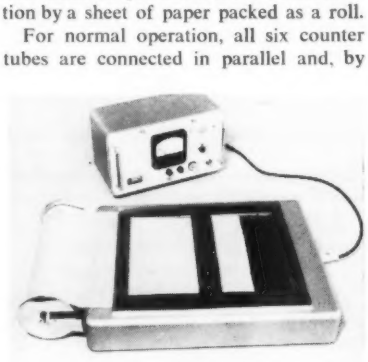
RADIATION DETECTION

hand monitor

Stonebridge Electrical's new hand monitor consists of two units, a detector, type E0A1, and a transistorized table type monitor with aural indication and two trip circuits.

The detector is provided with two windows, each having three counter tubes beneath. The tubes are protected by a grating and two foils, a lower one preventing the entry of light, and the upper, a mylar foil, for mechanical protection. The latter is protected from contamination by a sheet of paper packed as a roll.

For normal operation, all six counter tubes are connected in parallel and, by



Although the Stonebridge radiation detector is primarily a hand monitor, with a suitable grating, it can be used for checking footwear

means of a selector switch, each counter tube can be tested individually for the presence of background.

★ 211

RADIOACTIVITY IN WATER
high sensitivity monitor

Elliott Nucleonics' new water radioactivity monitor, type ND.2151, has a full-scale output of 50 counts/min, corresponding to 200 $\mu\mu$c of strontium 90, and a water sampling rate of 20 l per week.

The sampling unit, which contains a Geiger-Muller tube of the thin wall beta-gamma halogen quenched type, is mounted in a perspex tube forming the measuring chamber which also contains the ion exchange resin. The flow of sampling water is controlled by an electrically

Elliott Nucleonics water radioactivity monitor consists of a sampling unit and an indicating unit. Average counting rate is continuously recorded but an alarm unit may be included to work when a pre-determined count rate is reached

operated timing mechanism working in conjunction with a variable throttle valve.

Pulses from the Geiger tube are inverted and shaped in a pre-amplifier unit, and fed to a ratemeter which provides an output proportional to the counting rate averaged over about 10 minutes.

★ 212

INDUSTRIAL RADIOGRAPHY
portable tank units

Two Muller industrial X-ray portable tank units, from Research and Control, are claimed to give fully consistent radiographs through automatic kV application.

The desired kV value and exposure time are pre-selected and automatic operation follows when the exposure button is pressed. The kV is applied in two sequential stages, providing full electrical safeguards even when maximum kV is selected. Excellent duty cycles are also claimed through the use of an internal heat exchanger with forced circulation of insulating oil. The control box, suitable for either unit, incorporates both voltage and thermal overload protection, in addition to a blinker device for the connexion of a high-tension warning lamp.

The new Muller 55 lb model K and 84 lb model L X-ray tank units for industrial radiography. A button control box suitable for either unit allows pre-selection of kV value and exposure time

Model K, for a maximum output of 140 kV 5 mA, has a 1·2 mm focal spot and weighs 55 lb; Model L, for a maximum output of 200 kV 5 mA, has a focal spot of 1·6 mm and weighs 84 lb.

★ 213

NON-DESTRUCTIVE TESTING
image intensifier

By means of electronic intensification an X-ray image, 3000 times brighter than that available on a conventional fluoroscopic screen, is produced by Tracerlab's 3000X image intensifier. The increased brightness levels not only lead to reduced X-ray radiation levels but also to economies in generator and shielding requirements.

The system also accommodates, either separately or in combination, television, 16 and 25 mm movie, 35 mm still or polaroid cameras. Automatic brightness control maintains consistent frame by frame, high quality films.

★ 214

GAS PURIFIER
automatic drying

A self-contained unit, for hydrogen purification, combining the features of the Deoxo Catalytic Purifier with those of an automatically operated drying unit containing a Linde molecular sieve, has been developed by Engelhard Industries.

The Deoxo Puridryer, having a maximum capacity of 100 s.c.f.h., will purify normal commercial grade hydrogen to give a gas with an oxygen content of less than 1 p.p.m. By use of the molecular sieve, as the drying agent, it achieves a dew-point as low as minus 100°F, which enables the gas to be fed directly to a furnace.

The platinum metals catalyst used in the Puridyer to remove oxygen requires no re-activation, and unless poisoned by sulphur compounds, carbon monoxide, chlorine, and some organic compounds—which are rarely found in commercial hydrogen—it should last indefinitely.

The Puridryer may also be used with other gases such as nitrogen, argon, neon and saturated hydrocarbons, providing that two volumes of hydrogen are present in the gas to react with each volume of oxygen impurity to be removed.

★ 215

RADIATION DETECTORS
solid-state devices

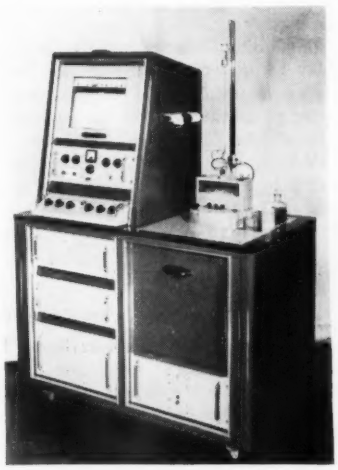
Much smaller than photomultiplier crystal combinations currently in use, a solid state particle detector has been developed by Semi-Elements that changes resistance by varying the amount of radiation present. In addition, it does not show any fatigue effects over prolonged periods of radiation.

Its present application is in the form of an X-ray device, one application being the quality control of steel rolling where the steel passes between the detector and an X-ray source. Work is also in progress for the development of a more efficient solid state particle detector for gamma rays using a single crystal.

★ 216

POLAROGRAPHIC ANALYSIS
pulse technique used

Manufactured by Southern Instruments, a pulse polarograph has been developed at Harwell that overcomes the limitations



The AERE Pulse Polarograph is a thermostatically controlled electrode system incorporating a self-contained hydrogen generator for deoxygenation

of square wave polarography when applied to irreversible reductions. It has the advantage of being capable of operation with base electrolytes 100 times more dilute.

The instrument is capable of producing both normal and derivative polarograms, detection of reversibly and irreversibly reduced ions at concentrations of 10^{-8}M and 10^{-7}M respectively, being possible. Effects due to residual current, and to high concentrations of ions reducing at a lower potential, have been largely eliminated.

★ 217

PULSE GENERATOR

fast repetition rates

The Du Mont Pulse Generator, Type 404, recently introduced by Aveley, provides continuously variable repetition rates from as high as 100,000 p.p.s. down to a single manually-triggered pulse.

Front panel switching of the Du Mont pulse generator is arranged in channelled blocks according to function. All output controls are either switch or push-button actuated, and allow for any amplitude to be duplicated at any time with perfect accuracy

Special features are the rise and fall times of 0·02 and 0·025 microseconds (max.) respectively, and a continuously variable pulse width from 0·05 to 100 microseconds.

In addition there are facilities for pulse delay before or after trigger; an output trigger to synchronize external equipment; push-button multi-step attenuation calibrated in 0·5 dB steps to 59·5 dBs, and 50 V output to a load impedance of 50 ohms, with a maximum rise time of 20 milli-microseconds at full amplitude.

★ 218

WATER SAMPLER

fully automatic

Manufactured under licence from the NRDC, Elcontrol's automatic water sampler permits a sequence of tests to be taken at regular predetermined intervals. The Sampler consists basically of a complete self-contained unit fitted with twelve 20-oz sample bottles, each sealed by an airtight plug through which passes a rubber tube connected to an outlet.

Control is by way of pinch valves, each of which can be manually closed and subsequently re-opened electromagnetically. In addition to the bottles, associated tubing, and the valves, the unit contains a 15-day clockwork motor and a transistorized power pack driven by a 6 V lantern battery. The pinch valves are automatically opened at predetermined intervals controlled by the time clock.

★ 219

IN BRIEF

• **Printed circuits.** Belling-Lee have now developed a range of 8-way and 18-way connectors for their flat and flexible insulated ribbon feeder.

★ 220

• **Gas blowers.** The RBS Holmes-Connersville positive blower has been modified to operate at 15 lbf/in². For gases other than air, mechanical shaft seals can be fitted. In the event of an oil seal failure, gas contamination is impossible.

★ 221

• **Temperature measuring camera.** A new infra-red television camera tube, introduced by EMI Electronics, coupled with an oscilloscope, can be used to measure to a high degree of accuracy temperatures from 450° upwards. Also available is a new vidicon tube that can be used to obtain television pictures from an ultra-violet microscope.

★ 222

• **Contamination protection.** A new self-baking plastic coating, developed by Evershield and marketed in the UK by Acalor, has been used in certain areas at Bradwell for protection against radioactive contamination.

★ 223

• **Radiation warning.** For the user of isotopes, three types of self-adhesive warning signs are available from Continental Distributors: type CD1, in 72-yd rolls, each containing some 850 labels; CD2, in 18-yd rolls, each with about 420 labels; and a larger 9 × 2½-in sign.

★ 224

• **Spectrophotometer glass.** For the rapid and accurate calibration of recording spectrophotometers, Corning have developed a special glass that is combined with holmium and transmits radiant energy in the ultra-violet region between 200 and 300 mμm.

★ 225

• **Low radioactivity glass.** 'Lorad' Glass 7285, developed by Corning, has a radioactivity of less than 100 counts/min/kg, or less than 6% of comparable glasses. It is to be used for bulbs, headers, and other components for photomultiplier tubes.

★ 226

• **Cable sheathing.** Good mechanical properties, good oil, solvent and fire resistance, and excellent abrasion resistance, are claimed by British Geon for a new cable sheathing material made from a blend of Geon PVC and Hycar nitrile rubber.

★ 227

• **Miniature potentiometer.** Manufactured under licence by Miniature Electronic Components, the TP5 single turn rotary potentiometer is capable of dissipating 1½ W at 80°C; has a temperature range of −55°C to 150°C, and is available in ten standard values ranging from 50–50 kΩ. It has a maximum diameter of 0·5 in and an overall length of 1·14 in.

★ 228

• **Analogue-digital converter.** 8192 codes per revolution without gearing and modular plug-in components are two features designed into the Digisyn, type RD-13G, converter introduced by Wayne-George.

★ 229

• **Liquid scintillator.** Pilot Chemical's newly introduced 'Liquifor', a 25 × concentrate of PPO and POPOP in purified toluene, is a pre-mixed liquid scintillator that saves weighing and storing time and reduces the chance of error.

★ 230

• **Steam trap.** Midland Industries have added to their range the 'Mil Thermatic' for the consistent discharge of condensate at steam temperature, from no load to maximum. In sizes ¼-in and ½-in, with a manganese bronze body it can be used from 5–250 lbf/in², or in stainless steel, from 5–400 lbf/in².

★ 231

• **Arc welding generator.** A new generator for on-site use has been introduced by Petbow that withstands the inherent vibration of diesel engine drive. A special field system provides continuous current adjustment between minimum and maximum at a near constant open circuit voltage.

★ 232

• **Leak detector.** Working with helium, the new Crosby-Teletronics series 700 mass spectrometer is capable of detecting air leak rates of 10^{-12}cm³/sec, 10^{-6}μm ft³/h.

★ 233

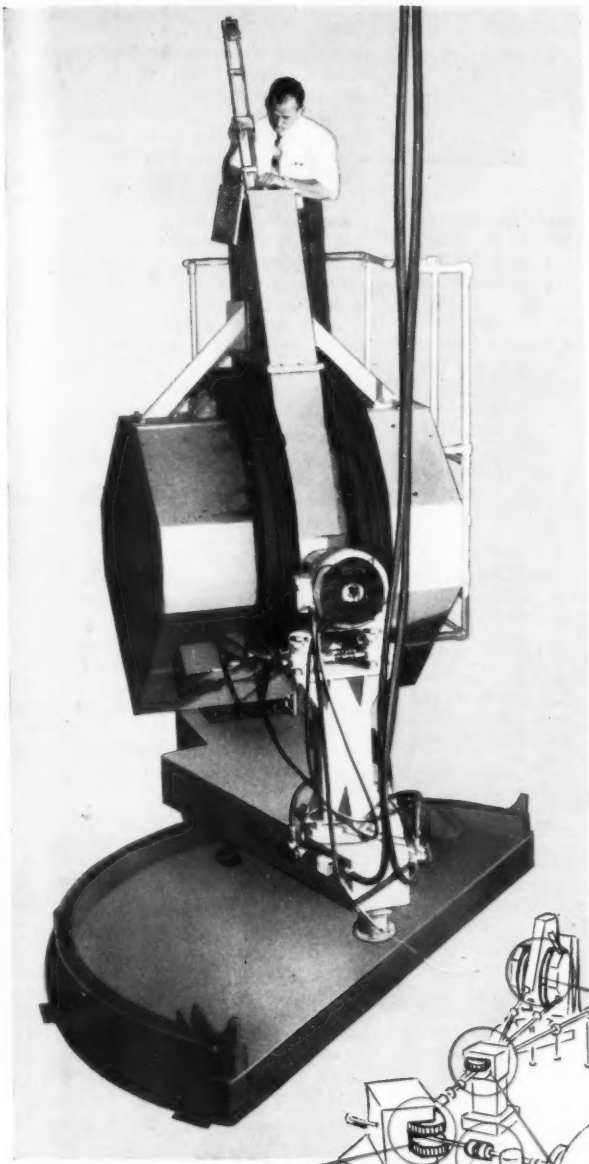
• **Induction heaters.** New 50 kW and 100 kW heaters recently added by Radio Heaters, that operate at frequencies between 1kc/s and 10 kc/s, use for output power English Electric's vapour cooled triodes, BY1121 and BY1102, instead of motor alternators.

★ 234

• **Magnesium oxide.** As a possible maser or laser material, Semi-Elements have recently made available magnesium oxide doped with the following rare earths: praseodymium oxide, samarium oxide and neodymium oxide. Specimens can be obtained either as single crystals, 1–3 mm, cross-section, × 4 mm long, or in larger polycrystalline form.

★ 235

★ *For further information on any item, circle the appropriate number on the reply card facing p. 114.*



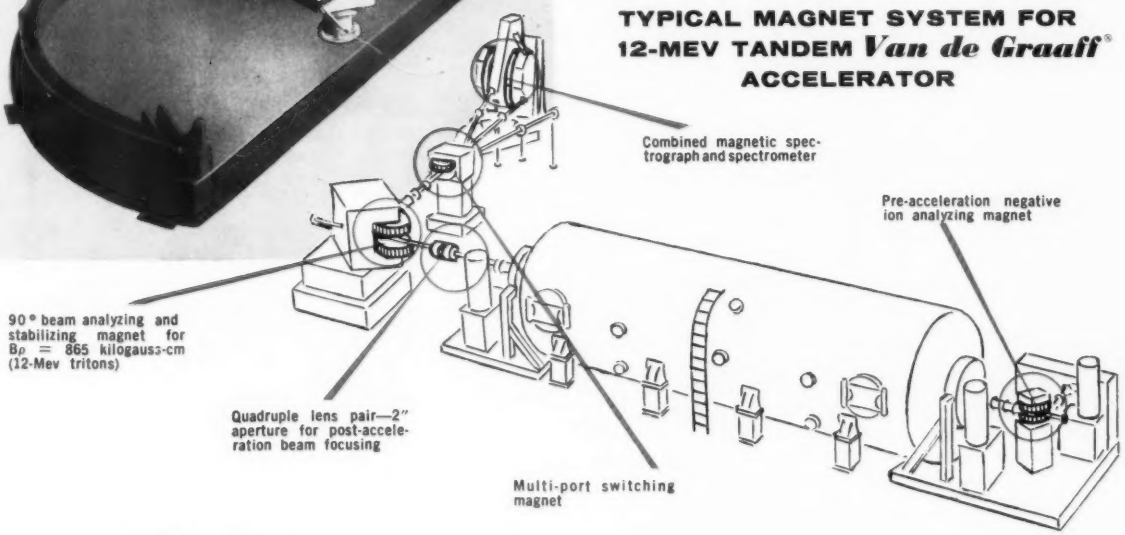
NUCLEAR PARTICLE ANALYZING MAGNETS

Combined Magnetic Spectrograph and Spectrometer* designed and built for Chalk River Laboratories, Atomic Energy of Canada, Ltd., for energy analysis of protons, deuterons, and alpha particles.

- Magnetic rigidity —
  Up to $B\rho$ = 865 kilogauss-cm (12-Mev tritons)
- Resolving power (spectrograph) —
  $E/\Delta E = 10^3$ or better
- Solid angle (spectrograph) —
  $\Omega = 1.4 \times 10^{-3}$ steradians (max)
- Solid angle (spectrometer) —
  $\Omega = 0.9 \times 10^{-2}$ steradians (max)
- Reaction angle —
  θ = 0 to 135 degrees
- Detector —
  Nuclear track plate and scintillation counter

*For further technical reference, see H.A. Enge, RSI **29**, 885 (1958)

TYPICAL MAGNET SYSTEM FOR 12-MEV TANDEM *Van de Graaff*® ACCELERATOR


Combined magnetic spectrograph and spectrometer
Pre-acceleration negative ion analyzing magnet
90° beam analyzing and stabilizing magnet for Bρ = 865 kilogauss-cm (12-Mev tritons)
Quadruple lens pair—2" aperture for post-acceleration beam focusing
Multi-port switching magnet

For detailed information on magnets and accelerators, write to Technical Sales:

HIGH VOLTAGE ENGINEERING CORPORATION

BURLINGTON, MASSACHUSETTS – U. S. A.

Circle **No 49** on reply card for further details

BUSINESS NEWS

OLDBURY SITE CONTRACT **Sir Lindsey Parkinson and Co** have been awarded a £2·2 million contract by the **Central Electricity Generating Board** for the circulating water system river works intended for the Oldbury nuclear power station. The contract will include the building of a reservoir on the river foreshore and site preparation for the station.

HANDLING EQUIPMENT EXTENDED **Nuclear Equipment Ltd,** jointly owned by **Savage and Parsons Ltd** and **General Mills Inc.,** now offers an extensive range of handling equipment for radioactive materials. With three new manipulators filling the intermediate requirement of 10–200 lb, the company's products range from the small pistol grip type to the mechanical arms capable of lifting 5000 lb. Existing contracts for the NE9 master slave manipulators include 60 from the UKAEA (see *New Products* this issue).

ULTRA - MILES ELECTRONICS LINK A one-third share in **Miles Electronics Limited** is to be purchased by **Ultra Electronics Ltd.** The association is expected to widen the scope of both companies' activities. As a result of this tie-up, the share capital of Miles Electronics Limited will now be equally owned by the Miles family, Ultra Electronics Limited and Lombard Development Corporation Limited. Mr A. V. Edwards and Mr. L. R. Crawford, directors of Ultra, will join the board of Miles.

TRAWSFYNYDD CONTRACT Pipework contracts worth about £300,000 have been obtained by **Aiton & Co,** Derby, from **Atomic Power Constructions Ltd.** They are for the supply and erection of steam, feed, circulating water, and certain ancillary services for the two reactors now under construction at Trawsfynydd.

PHILIPS SUPPLY ISOTOPES The commercial products of the **Philips** synchrocyclotron installed at Amsterdam are now available from **Research & Control Instruments Ltd.** They include a number of items unobtainable from other UK sources. Neutron sources suitable for the activation analysis of metals, and for the polymerization of materials can be supplied. Target materials are offered together with sealed sources for the calibration of spectrometers and measuring equipment. Arrangements can be made for the irradiation of customer's own materials.

CEGB ORDER FOR MILES ELECTRONICS **Miles Electronics Limited,** Shoreham, have been awarded a contract by the Central Electricity Generating Board to provide a dual-sectioned reactor fuel element rapid thermal cycling rig to high accuracy specifications which will utilize an analogue computer for programming and control. This follows a contract awarded to **F. G. Miles Limited** for a similar rig for **Atomic Power Constructions Limited.**

• **Mitchell Construction Co (Leeds)** has been awarded a contract by the **Yorkshire Electricity Board** for the construction of a reinforced concrete building to house the Board's new electronic computer.

• **Weir Valves Ltd** has changed its name to **Weir-Pacific Valves Ltd** as the result of entering into a manufacturing agreement with **Pacific Valves Inc.** of California.

• **Ultra Electronics Ltd** has a contract from **Atomic Power Constructions Ltd** for the development of a sector servo control system for the reactors at Trawsfynydd nuclear power station.

• **BP Energol** lubricants have been chosen for the Latina power station.

• **Lancashire Dynamo & Crypto** has received an order from **Fairey Engineering** for nearly 400 permanent magnet motors for operating the reactor control rods of Trawsfynydd nuclear power station.

• An order for a new high vacuum brazing furnace worth more than £7500 has been placed with **Vacuum Research (Cambridge) Ltd** by the Admiralty.

OVERSEAS

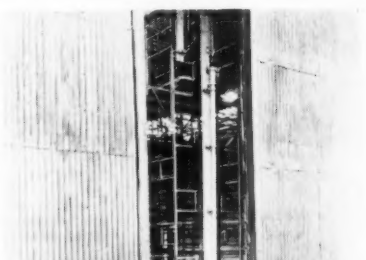
BAIRD STAKE IN DUTCH FIRM A controlling interest in a Dutch nuclear instrument company has been acquired by **Baird-Atomic Inc.** of Cambridge, Mass. The American firm, which specializes in the manufacture of scientific instruments, has obtained a major share of the stock of **Electronisch Kernfysisch Apparatenfabriek NV** (EKAF) which will now be known as **Baird-Atomic Holland, NV.** The move, according to Mr Davis R. Dewey II, president of Baird, 'initiates a Baird-Atomic programme of stepped-up activity in the European market aimed at consolidating a position of leadership in the field of scientific instrumentation'. Baird-Atomic also operates a wholly-owned subsidiary in Kleve, West Germany.

FORUM ANNUAL REPORT The first really large nuclear power units are coming into operation and will provide the commercial operating experience necessary to assess the real prospects of atomic power. These words were addressed to members of the **Atomic Industrial Forum** by its President, Mr Francis K. McCune, in the annual report of the forum for the year ended June 30, 1960. Mr McCune added that the first nuclear plant sold in international commerce would also be coming into operation soon and valuable experience was being accumulated from prototype plants operating for some years now. This represented real and specific progress. The Forum's annual report summarizes the action programme undertaken by this association to solve problems inhibiting development of the full potential of the peaceful uses of atomic energy.

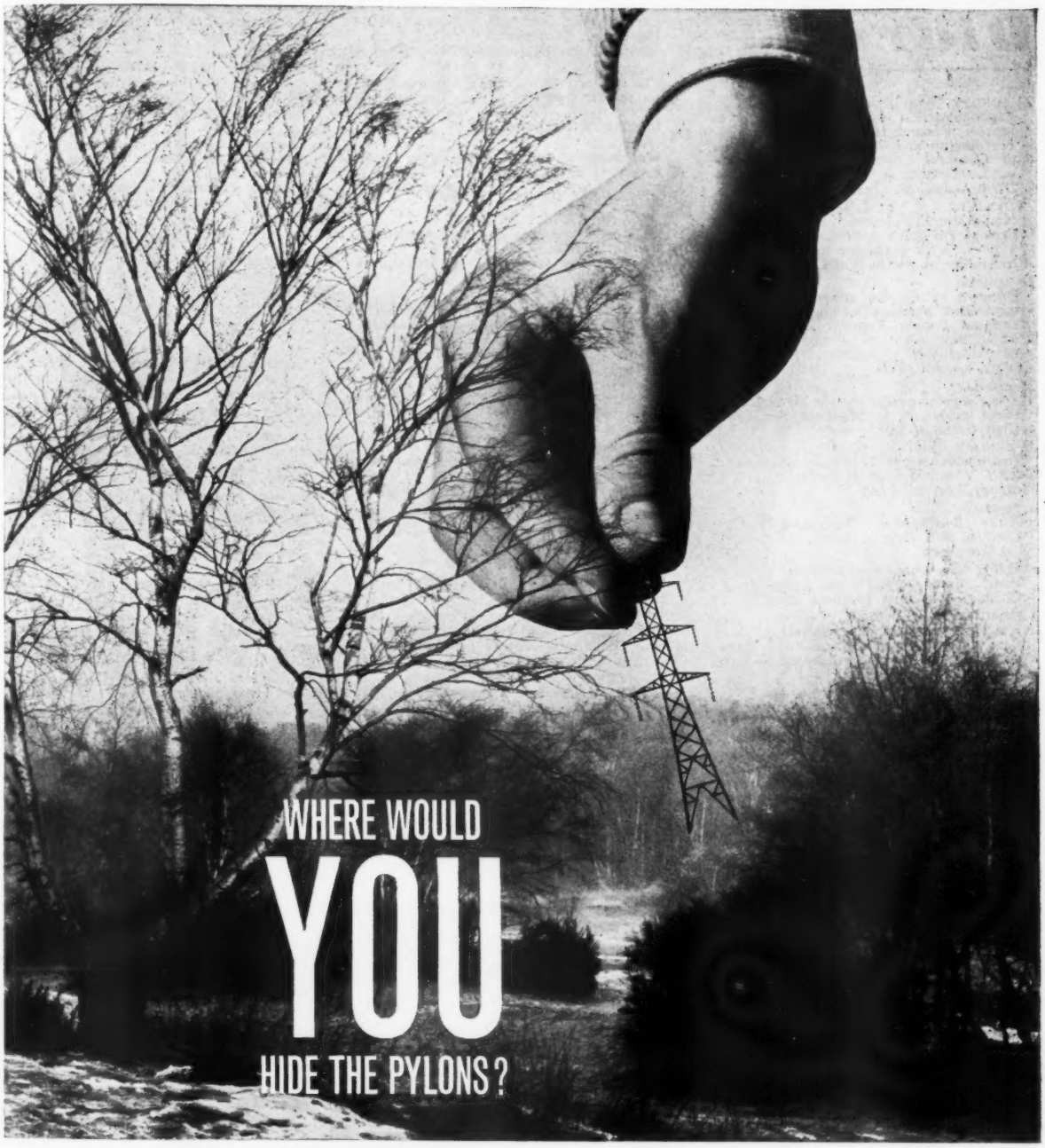
NATURAL CIRCULATION REACTOR The USAEC has awarded a contract to **Giffels and Rossetti Inc.,** Detroit, for the performance of architect-engineering services for the design of the site facilities for the Natural Circulation Reactor Test Plant to be built at Arco, Idaho. The Natural Circulation Reactor Test Plant is being developed at the AEC's Knolls Atomic Power Laboratory which is operated by the **General Electric Company.** A natural circulation reactor eliminates the need for large circulating pumps and associated electrical generating and control equipment, reducing capital costs.

• The **Dominion Bridge Company Ltd** is to supply two steam reheaters for Canada's first large nuclear power station at Douglas Point, Ontario. The 200 MW plant, CANDU, is expected to come into operation in 1965.

• The Yugoslav Atomic Energy Commission has ordered a neutron diffraction apparatus from the German firm, **Maschinenfabrik Nuernberg - Augsburg** (MAN). It is to be installed at the Boris Kidric Institute at Vinca.



BEPO RIG An in-pile rig for the AEA research reactor BEPO undergoes testing at Fairey Engineering Ltd's Heston works. With the rig it will be possible to irradiate metallurgical specimens at the temperature of liquid hydrogen



Not even trees can hide the pylons completely . . . but pylons there must be if people want the amenities that depend on electrical power. Over the next ten years Britain's power demands will double—and that means more overhead lines.

But although pylons can't be made invisible, power lines can be planned to follow the least conspicuous route, to take advantage of natural screens such as woods and hills, and only break cover when unavoidable. This kind of careful planning, which is going on all over the country today, is in the hands of the Central Electricity Generating Board, which is charged by Act of Parliament to provide an efficient and economical power supply to the nation, while doing everything possible to preserve the natural beauties of the countryside.

■ These advertisements are appearing in the farming and country magazines. The Central Electricity Generating Board thank electrical contractors for their co-operation in the past, and know that they will do all they can to preserve the amenities of the countryside.

THE CENTRAL ELECTRICITY GENERATING BOARD CEGB

Diary

24 JANUARY
Experimentation and reactor design in process research and development, W. Waddington and W. D. Betts, Institution of Chemical Engineers meeting, Birkenhead. Details, A. V. Bailey, 2 Finney Drive, Wilmslow, Cheshire

25 JANUARY
Non-destructive testing, R. W. Parish, Sports Pavilion, AWRE, Aldermaston, 3 pm South graduates section meeting, Institution of Mechanical Engineers

26 JANUARY
Pressure vessels for gas-cooled graphite moderated reactors, Literary and Philosophical Society Rooms, George Street, Manchester, 6.45 pm. Details, Institution of Mechanical Engineers, 1 Birdcage Walk, London, SW1

27 JANUARY
Some aspects of the solvent extraction of metal halides, A. G. Maddock, Windscale Club, Seascale, 8 pm

31 JANUARY
Instrumentation past, present and future, L. S. Yoxall, Society of Instrument Technology, London, 7 pm

1 FEBRUARY
X-ray fluorescence, Burlington House, London, W1. Details, Society of Analytical Chemistry

Diffusivities in aqueous solution, Midland Hotel, Birmingham. Details, Institution of Chemical Engineers, Midland branch

7 FEBRUARY
Nuclear propulsion for aircraft, A. D. Baxter, The College, Victoria Road, Swindon, 7.30 pm. Royal Aeronautical Society, Swindon branch meeting

Standards in plant engineering, Dr E. L. Diamond, Royal Society of Arts, John Adam Street, London, WC2, 7 pm. Details, Institution of Plant Engineers

9 FEBRUARY
The origin and solution of some industrial corrosion problems, E. C. Cambell, Liverpool Metallurgical Society, Department of Metallurgy, Liverpool University, 7 pm

17 FEBRUARY
First Croxon Memorial Lecture, **The evolution of non-destructive testing,** Dr L. Mullins, Caxton Hall, Westminster, 6.15 pm. Details, Secretary, Society of Non-Destructive Examination (Mr D. T. Carter, ESAB Ltd, Gillingham, Kent)

20 FEBRUARY
The influence of availability of enrichment on reactor type and design, Nuclear Energy Group discussion, Institution of Mechanical Engineers, 6 pm

21 FEBRUARY
Weldability of mild and low alloy steels, Engineers Club, Manchester. Members' meeting, British Welding Research Association

22 FEBRUARY
Thomas Hawksley Lecture, **Controlled Fusion Reactions,** Professor P. M. S. Blackett, The Institution of Mechanical Engineers, 1 Birdcage Walk, SW1

23 FEBRUARY
The Atomic Clock, J. Parry, The Society of Instrument Technology, Chester section meeting. Details, W. Trafford, 3 Heath Grove, Little Sutton, Wirral, Cheshire

24 FEBRUARY
Ion-exchange, Royal College of Science and Technology, Glasgow. Details, Society for Analytical Chemistry and Royal Institute of Chemistry

28 FEBRUARY
Safety of nuclear marine propulsion plant, joint panel, J. M. Murray and H. Pemberton, The Institute of Marine Engineers, 76 Mark Lane, London, EC1

Future months

9 MARCH
Design application and selection of automatic control valves, Liverpool branch, Society of Instrument Technology, 7 pm

Creep deformation, Liverpool Metallurgical Society, Department of Metallurgy, Liverpool University, 7 pm

21–26 MARCH
Electrical Engineers Exhibition, Earls Court. Details, Electrical Engineers, A.S.E.E. Exhibition Ltd, Museum House, Museum Street, London, WC1

5–7 APRIL
Electrical Contacts Symposium, London. Details, The Secretary, The Institute of Physics and The Physical Society, 47 Belgrave Square, London, SW1

17–19 APRIL
International meeting on **fluid sealing,** Ashford, Kent. Contributions welcomed. Details, Mr H. Stephens, British Hydromechanics' Research Association, South Road, Temple Fields, Harlow, Essex

20 APRIL—4 MAY
Engineering, Marine, Welding and Nuclear Energy Exhibition, Olympia, London. Details, S. W. Bridges & Sons Ltd, Grand Buildings, Trafalgar Square, London, WC2

29 MAY—2 JUNE
Conference, **Property changes in reactor materials and radiation damage,** Bristol. Details, A. Trevor Churchman, CEGB, Berkeley Nuclear Laboratories, 7 St Stephen's Avenue, Bristol 1

OVERSEAS

20–25 FEBRUARY
International **Convention on Semi-Conductor Devices,** Paris. Details, Societé Française des Electroniciens et des Radioélectriciens, 10 Avenue Pierre-Larousse, Malakoff (Seine) France

27 FEBRUARY—3 MARCH
Conference on **Analytical Chemistry and Applied Spectroscopy** and Exposition of modern laboratory equipment, Pittsburgh. Details, W. F. Harris, Programme Chairman, Pittsburgh Conference, Westinghouse Electric Corporation Research Laboratories, Pittsburgh 35, Pa, USA

17 APRIL
Conference to consider draft convention on **third party liability and indemnification resulting from operation of nuclear powered ships,** Antwerp, Belgium. Arranged by Comité Maritime Internationale

15–20 MAY
IAEA **Nuclear Electronics** Conference, Belgrade, Yugoslavia

21–24 JUNE
Fourth International **Light Metals** Congress, Leoben, Austria. Details, Montanistische Hochschule, Leoben, Styria, Austria

28 AUGUST—1 SEPTEMBER
International **Heat Transfer** Conference, Boulder, Colorado. Details, S. P. Kezios, c/o American Society of Mechanical Engineers, 38 West 39th Street, New York 18, USA

1962

27 MAY—2 JUNE
Fourth International Congress on **Prestressed Concrete,** Rome and Naples. Organized by Fédération Internationale de la Precontrainte

Industrial Literature

Radiation detection. RCA's catalogue of photosensitive devices and cathode-ray tubes has been brought up to date by the addition of data sheets covering multiplier phototubes 7200, 7264, 7265, 7326, 7764.

★ 251

Protective paint. Detel Product's range of protective coatings includes 'Atomicote' suitable up to 10^8 röntgens. Their leaflet outlines various applications, temperature resistance and drying times.

★ 252

Non-destructive testing. The inspection facilities of Solus-Schall cover X-radiography, penetrants, ultrasonic flaw detection and magnetic particle inspection. A new booklet discusses each method.

★ 253

Control systems. The 'Panalarm' annunciator system, that gives both visual and aural warning of off-normal conditions, is apparently being applied successfully in a widening number of industries. Panellit give details of the latest equipment available in a recent catalogue.

★ 254

Stress relief. Pre-heat and stress relieving units for welded pipes have been designed by Stress Relieving Services for arduous field and *in situ* conditions. An introductory leaflet discusses materials and heat treatment methods.

★ 255

Radiation equipment. Nuclear Enterprises' catalogue of scintillation phosphors, nuclear instruments and low level counting installations has been brought up to date and now includes the human body radiation monitor as supplied to Windscale.

★ 256

Reactor materials. Two new catalogues from the Compagnie des Ateliers et Forges de la Loire give details of their range of stainless steels and heat resistant steels, setting out mechanical properties and appropriate applications.

★ 257

Nuclear valves. Blakeborough's latest catalogue presents typical examples of fluid control valves produced for essentially nuclear applications. Each valve type described is accompanied by a list of the relevant installations, or work in hand.

★ 258

Research reactors. Continuing his series 'a plain man's guide to atomic energy', in the current 'Fairey Review' Mr Duncton switches to the research reactor field and includes a description of Winfrith's HECTOR for which Fairey are the major contractor.

★ 259

Computer programmes. Ferranti's latest revision of their 'Index to Computer Literature' covers library programmes for both the Pegasus and Mercury Computers. Others for the Sirius, Atlas and Orion computers are in preparation.

★ 260

Metal coatings. Heat resistant coatings by the metal spraying process, for the protection of steel again oxidation up to 1200°C, are discussed in a new Metallisation leaflet.

★ 261

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Book Reviews

Ionized gases

Ionization Phenomena in Gases by Gordon Francis Butterworths Scientific Publications, London, 1960. 300 pp Price 60s

This book was written to complement the standard textbooks on ionized gases, treating those branches of the subject which are closely linked with other branches of physics, and which cannot be studied except by intensive searching through the literature. As such it is an interesting and readable book covering a well-chosen variety of topics, well documented with references to original papers.

A concise introduction, of particular value to the more general reader, covers the fundamental processes of ionization, and this is followed by a full treatment of similarity laws. The chapter on alternating and high-frequency discharges is authoritative and extensively illustrated. Ionization phenomena in the upper atmosphere is also clearly described. The chapter devoted to the author's present field of research, that of controlled thermonuclear reactions, contains a full account of the pinch effect, the elementary theory of thermonuclear reactions, and brief descriptions of a selection of experimental devices in current use. Finally, a chapter on plasma oscillations and waves introduces the reader to a subject of growing importance in plasma physics.

Although primarily intended for those beginning post-graduate research, this book can also be strongly recommended to electrical engineers who find themselves engaged on thermonuclear research.

P. A. Davenport

Fusion research

Nuclear Fusion, edited by William P. Allis (The second Geneva series on the peaceful uses of atomic energy. General editor J. G. Beckerley) van Nostrand, Princeton, NJ, 1960. Price 94s

Work on thermo-nuclear fusion was classified until about 10 years after the war. When the results were released it seemed as if the practical solution was fairly close. Alas, we know today that it will take a long time to solve the problem, if a technical and economical solution is to be found at all. In the meantime science has been forced to reduce its pace, and, instead of taking a direct route, has embarked on fundamental research on electric discharges and plasmas. This can be seen from most of the contributions presented at the Geneva Conference in 1958.

This book is a most welcome addition to the literature on thermo-nuclear fusion and it contains not merely summaries of the 105 papers presented (two thirds came from the US), but a re-write of the material in hand. The editor, using a uniform notation of symbols, has tackled the task systematically. There are sections on survey papers, plasma diagnostics, interactions between plasma and electro-magnetic waves, stability and dynamics of the plasma, machines and the contracting plasma (pinch). Papers which depart too much into the realm of conjecture have been excluded.

On the whole the book is readable and should be of much interest to nuclear engineers and physicists, as well as to non-specialists with a certain background. The jargon (e.g. 'crowbar the torus for the fast pinch') has been largely omitted. The experimental and descriptive papers are particularly well presented—as is to be expected from a theoretical physicist of Allis' rank. The mathematical sections are perhaps less easily digestible because too much has been condensed into too little space. Since the editor, a consultant at Los Alamos, has contributed a great deal to US advances, his critical comments, mostly associated with non-American work, are valuable. The reader will also find what can be studied with a small laboratory apparatus, and what are the reasons for spending such a great deal of brainpower, time and money on the development of large machines. There are numerous diagrams, oscillograms and tables and they are excellently produced and well explained.

A. von Engel

Transducer design

Instrumentation in Scientific Research—Electrical Input Transducers by Kurt S. Lion, McGraw-Hill, New York and London, 1959. 324 pp Price 74s

This book should prove of real value to all who wish to use or incorporate input transducers in their designs. It is divided into five main sections dealing with mechanical input transducers, temperature transducers, magnetic transducers, electrical transducers and radiation transducers. Treatment is very detailed; for instance, in the first section there are accounts of transducers for linear dimensions, e.g. resistive systems, inductive thickness gauges, capacitive systems, thickness determination from measurements of electrical breakdown, ultrasonic methods, radiation thickness gauges, as well as separate dissertations on transducers for displacement of force, for velocity of acceleration determination, liquid-level transducers, pressure transducers, transducers responding to the flow of liquids and humidity transducers. The book is much more than a collection of facts and figures, it presents successfully an established order in this vast field of experimental methodology and instrumentation. In every case there is a proper physical account of the principle of operation of the new device, amply illustrated with line drawings and in some cases by actual photographs, with a commentary of the particular uses of the device as compared with the other available methods. The matter is well presented and is in the right form to be easily assimilated by the student. Thus, in discussing the operation of photomultipliers, the author distinguishes very early between the three methods of use, namely: countery single electrons; a chopped light-beam and a.c. amplification; and the use of d.c. amplification, and makes clear the special uses of each method.

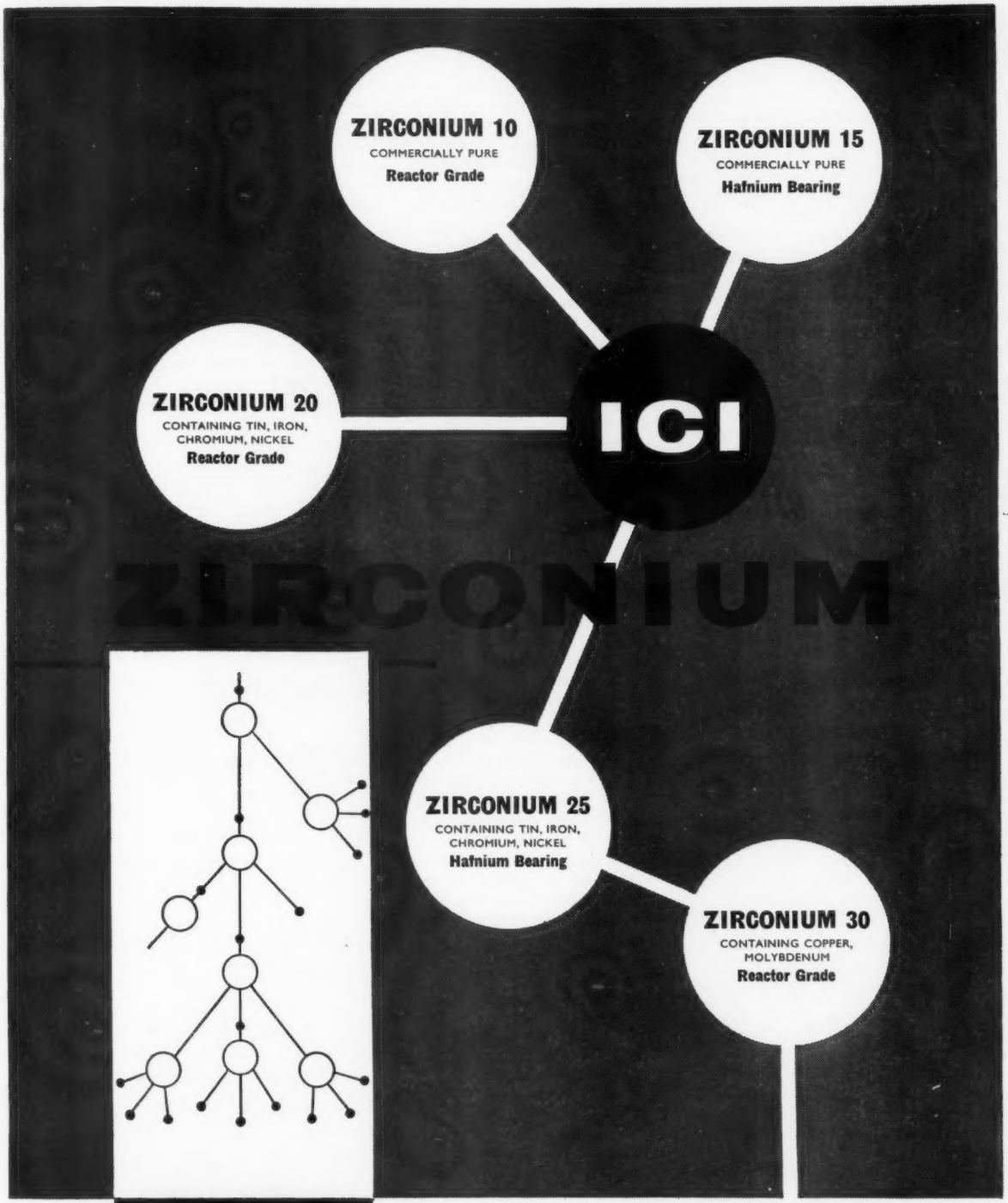
Denis Taylor

Plutonium metallurgy

Extractive And Physical Metallurgy of Plutonium and Its Alloys edited by W. D. Wilkinson Interscience, New York and London, 1960. 314 pp Price 79s

This book is the first to appear which is wholly devoted to the study of the metallurgy of plutonium despite the fact that the first conference on the metal plutonium antedated the Symposium, on which this book is based, by nearly eighteen months. The book appeared little more than a year after the completion of the Conference on which it is based. The contents are largely determined by the papers offered to the Symposium held in San Francisco during February 1959 and sponsored by American organisations concerned with mining and extraction. In fact, only one third of the papers submitted were in this field, possibly because of the dearth of declassified information available at the time of the meeting. As a result, a somewhat unrepresentative selection of papers, predominantly from one American laboratory, make up the greater part of the Symposium.

The papers on Extractive Metallurgy cover in condensed form all that can be said concerning the conversion of pluto-



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Book Reviews

nium from its compounds to the metallic form. They are written by persons who are acknowledged for their contributions in this field in the United Kingdom and France and in various laboratories in the United States.

The remaining papers on Physical Metallurgy are on somewhat specialized aspects and will disappoint those who may reasonably expect from the title of the book an authoritative outline of research in this field. Nevertheless, they will be of considerable interest to the specialists, who have hitherto been unable to obtain a full account of the proceedings of the meeting. It is clear that this weakness has been apparent to the Editor who has made a courageous attempt to remedy some of these omissions by providing a comprehensive annotated bibliography and by reviewing the properties of metallic plutonium. This suffers from the minor defects to be expected from a person who is not himself an expert in the field. For example, the density data for alpha plutonium is inaccurate and obsolete; on the opposite page there is also a discussion of the elongation of high purity and standard purity plutonium between the phase changes which fails to convey the significance of the results that are quoted; similarly there is a discussion of Varley's treatment of expansion behaviour which misses the vital contention that a negative coefficient is possible without valency change. The bibliography (which includes indicative abstracts) is useful and comprehensive.

M. B. Waldron

Plasma physics

Symposium of Plasma Dynamics edited by F. H. Clauser and others Pergamon Press, London; Addison Wesley, Reading (USA), 1960. 369 pp Price 84s

In a rapidly expanding subject like plasma physics, it is difficult to keep abreast of recent developments and the many and varied applications. The time comes when an overall summary and appraisal is required. With this in mind, the US Air Force Office of Scientific Research asked the National Academy of Sciences to organize an International Symposium on the subject of Plasma Physics. This Symposium was held at Woods Hole, Massachusetts, during the first week of June, 1958. The proceedings have now been published under the title of 'Plasma Dynamics'. Without doubt this is one of the most useful and valuable handbooks yet published in this field.

These proceedings do not, however, consist of a series of formal lectures; the book is divided into chapters. Each chapter is devoted to one particular aspect, such as 'Flight-magnetohydrodynamics', and consists of contributions from various members of the Symposium, a chapter editor welding these contributions into a readable consistent whole. The style is naturally varied and controversial issues, such as, for example, the importance and nature of line radiation losses from a plasma, have not been avoided. On the whole a good balance has been maintained between theory and experiment, although in many cases one feels the need for more detail. This, however, can be found in the references given in the remarkably comprehensive bibliography at the end of the book.

The only way to indicate the scope of the book is to give several of the chapter headings. These include 'The Problems of thermonuclear fusion and high temperature plasmas'; 'The Dynamics of electron beams'; 'Flight-magnetohydrodynamics' and chapters on cosmic, solar, planetary and interplanetary magnetohydrodynamics. One of the most comprehensive chapters is that on 'Statistical plasma mechanics'. Although there has been a considerable degree of progress in this subject over the past two years, this chapter provides one of the best overall introductions to the subject. Besides dealing with the Maxwell-Boltzmann equation and the associated equations of change, it discusses the validity of these equations in relation to the Kirkwood-Bogoliubov equations. The applicability of the Fokker-Plank equation to a plasma is also considered, while a short section on Bohm's and Pine's use of collective co-ordinates is included.

Although this book is primarily a handbook for people already engaged in the field, the newcomer can still study it with profit.

B. S. Liley

Nuclear photons

Nuclear Photodisintegration by J. S. Levinger Oxford University Press, 1960. 144 pp Price 15s

For perhaps the past twelve years, the nuclear photo effect has been the subject of a great deal of detailed investigation. The appearance of this book, the first on the subject, will be welcomed both by researchers in the field and students, who wish to become acquainted with it.

Professor Levinger begins by developing the basic concepts of oscillator strengths, the multipole expansion, and dipole sum rules from the more familiar example of atomic transitions, before introducing the equivalent but different nuclear case. The mathematics is terse, but reasonably comprehensive, and this introduction well repays a thorough and careful reading. The chapter concludes with a brief review of the experimental parameters of the giant dipole resonance and its modes of decay. Then follow specific chapters devoted respectively to the photodisintegration of the deuteron, sum rule estimates of the various moments, mean energies, and integrated cross-sections of the resonance, and to a discussion of electromagnetic transitions between discrete states below the continuum.

The final chapter is devoted to a study of the characteristics of the disintegration, and the branching ratios for various photo-reactions, and the discussion is closely related to the predictions of the models reviewed earlier. Experimental results are quoted wherever relevant.

The author is to be complimented for providing, in such a condensed yet comprehensible form, an excellent overall picture of the state of the subject, and current thinking in it.

K. H. Lokan

New Books

• *Engineering management* 2nd edition by Struan A. Robertson Blackie, London 1960 467 pp Price 30s

★ 262

• *Fundamentals of digital instrumentation* by D. S. Evans Hilger & Watts, London 1960 39 pp Price 7s 6d

★ 263

• *Resonance absorption in nuclear reactors* by L. Dresner Pergamon, London 1960 131 pp Price 40s

★ 264

• *Practical nucleonics* A course of experiments in nuclear physics by F. J. Pearson and R. R. Osborne Spon, London 1960 208 pp Price 37s 6d

★ 265

• *Progress in Nuclear Energy, Series IV*—Technology, Engineering and Safety, volume 3, edited by C. M. Nicholls Pergamon, London 1960 448 pp Price £5 5s

★ 266

• *Vacuum technology transactions* Proceedings of the 6th National Symposium, 1959, edited by C. R. Meissuer Pergamon, London 1960 335 pp Price £6

★ 267

• *Dictionnaire - agenda - annuaire - atomique 1961* Kister, Geneva; or Grange-Batelière, Paris 1961 100 pp Price NF17, SwissF15

★ 268

• *Recent research on controlled thermonuclear fusion* International Atomic Energy Agency, Vienna 1960 Review Series No 4 80 pp Price 6s (per HMSO)

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• *Progress in nuclear physics*—Volume 8, edited by O. R. Frisch Pergamon, London 1960 304 pp Price 90s

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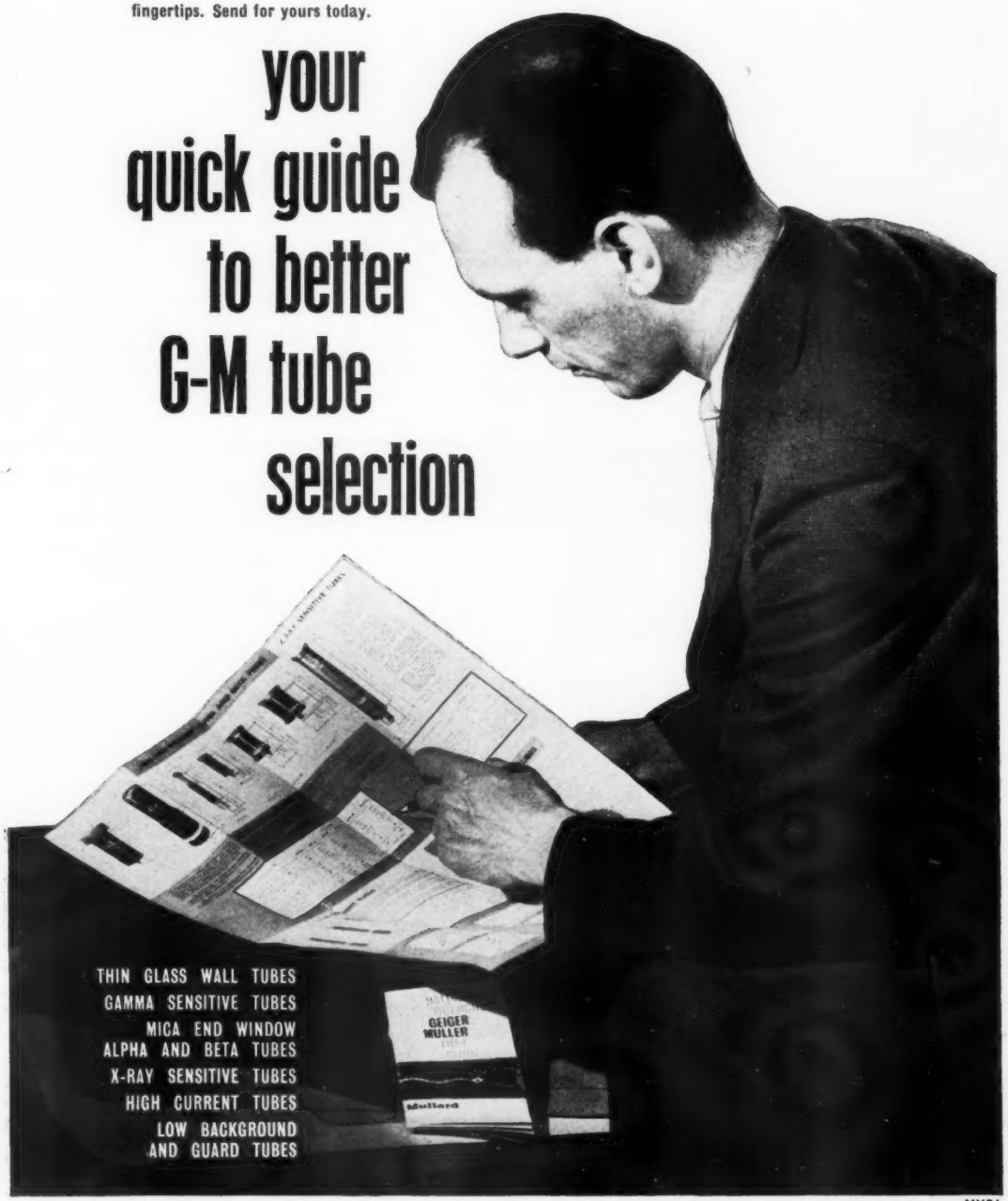

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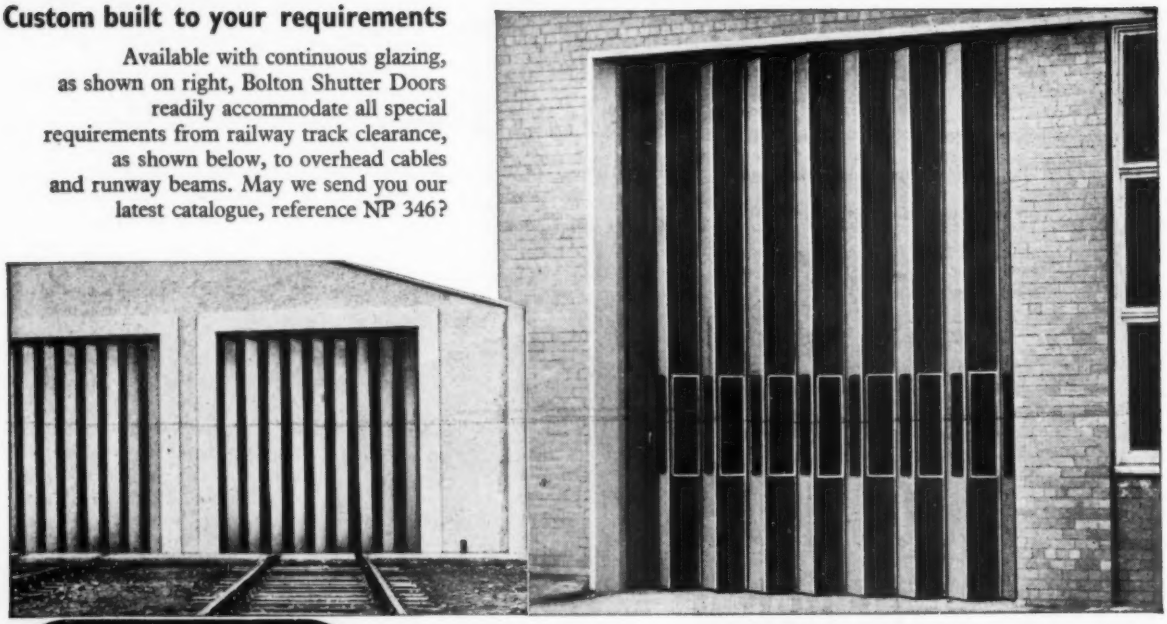

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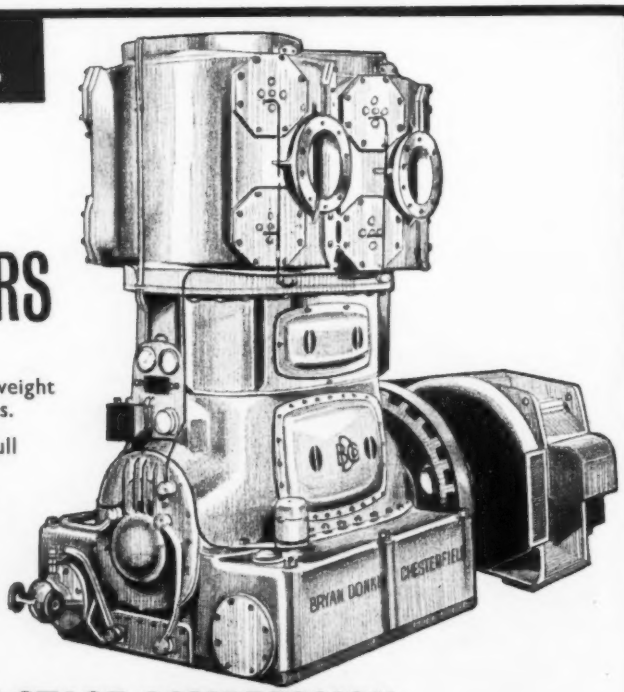

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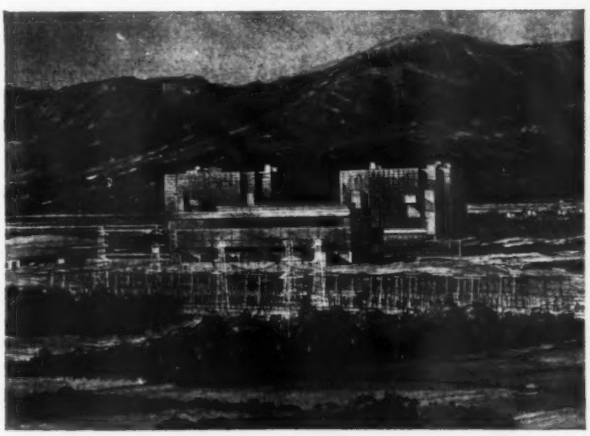

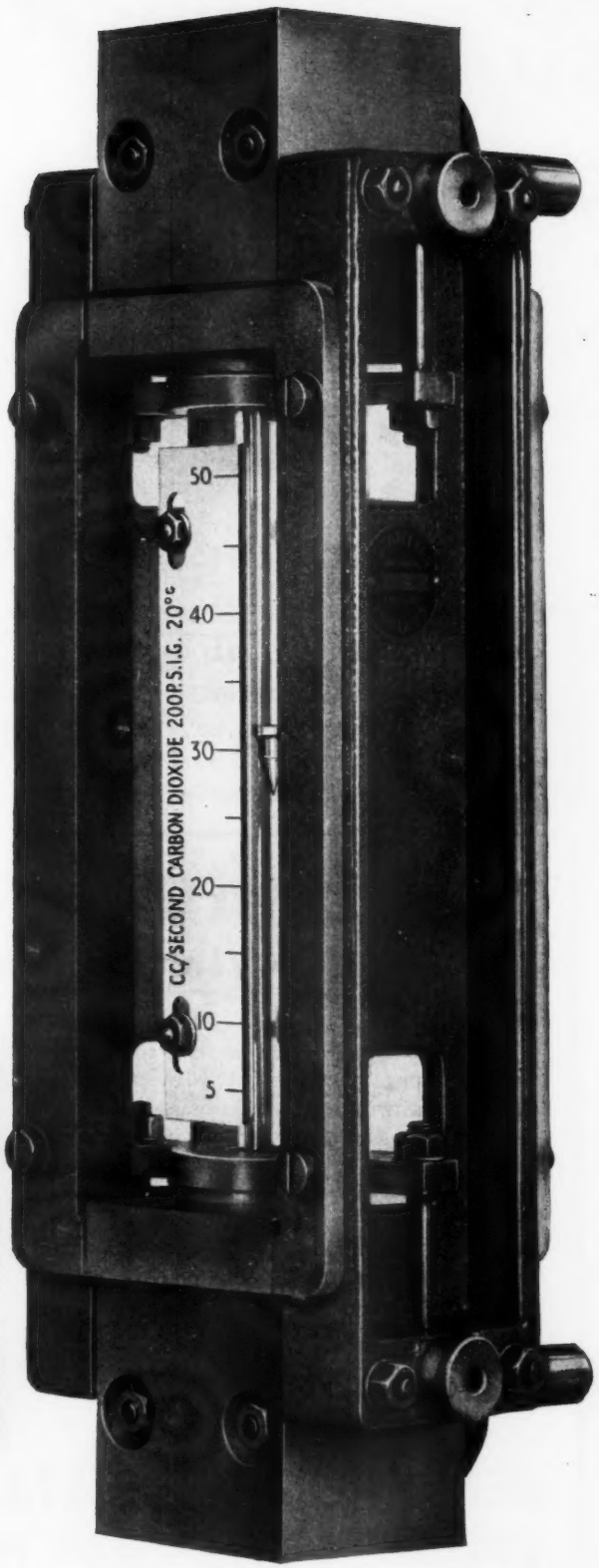

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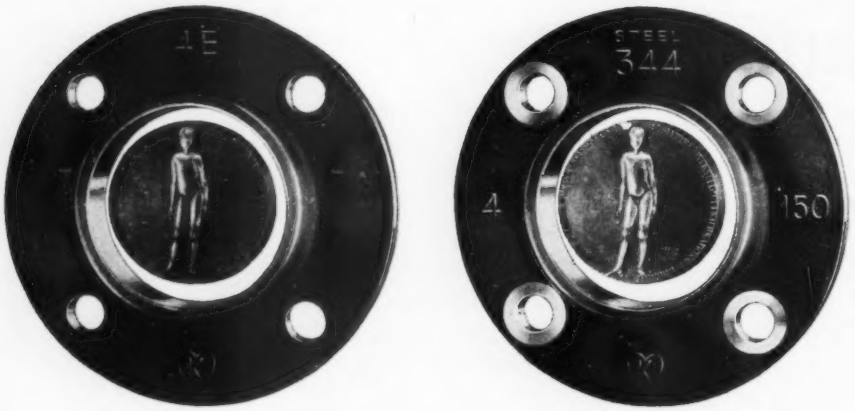

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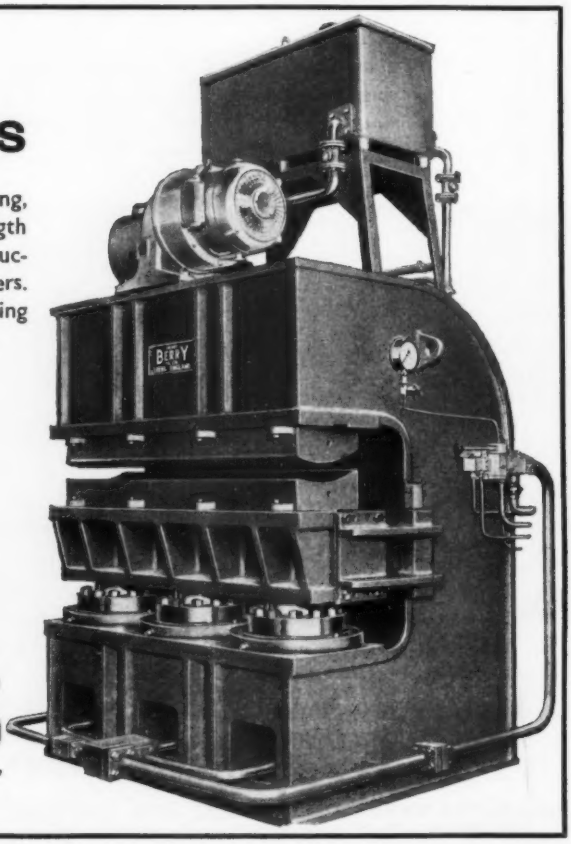

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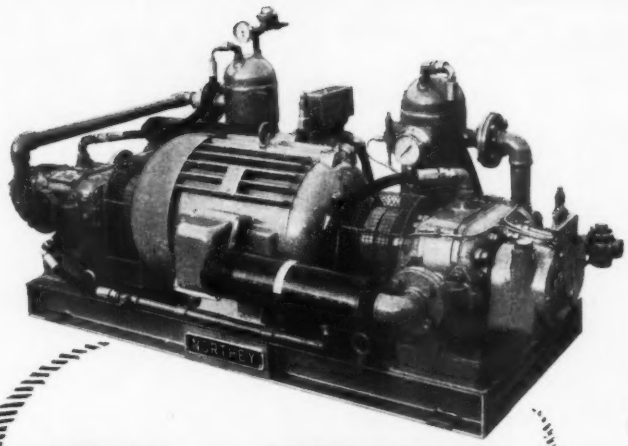

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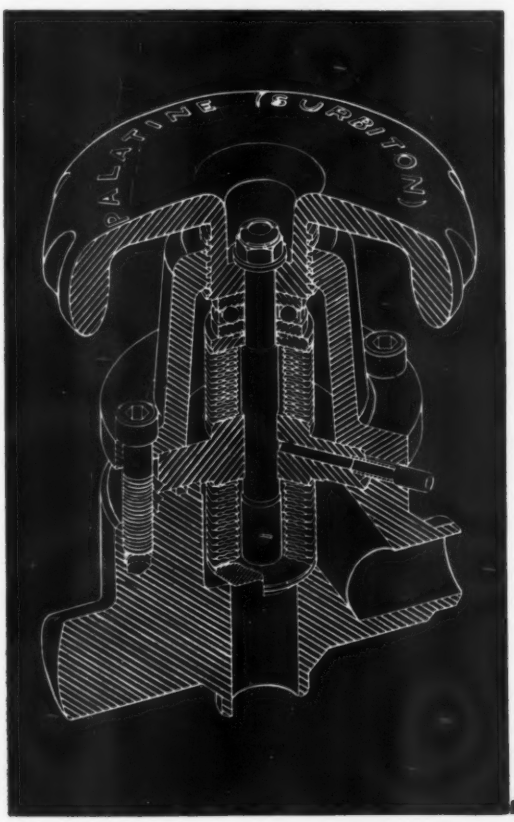

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AVENUE PARADE, ACCRINGTON, LANCS. Tel: Accrington 35611-2

Westover Isotope Coffins & Carriers

- Accommodate at least 6 types of isotopes from activity of 1/100 Curie to 59,000 Curie.
- Lead shielding designed for a dose rate of radiation 2.5 Milliroentgens per hour at a distance of 1 metre from source.
- Guaranteed against lamination, porosity internal cavities and interstices in surrounding lead.
- Cylindrical or spherical designs available.

Westover Nuclear Equipment Company Ltd.
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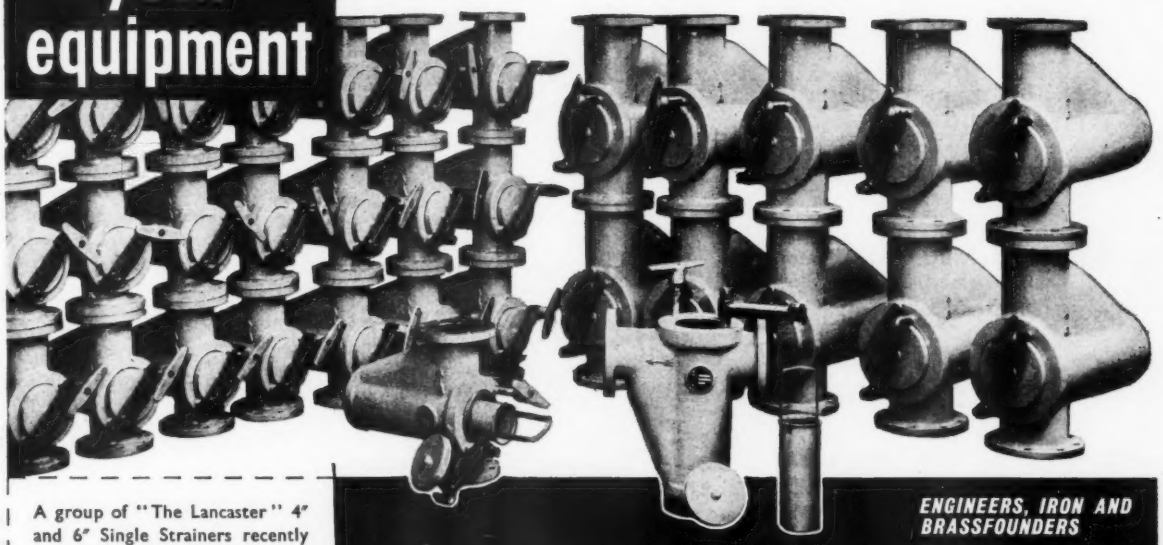
Protect your equipment

with "The Lancaster" pipeline strainers



A group of "The Lancaster" 4" and 6" Single Strainers recently shipped to Caltex Ocean Terminals in the Far East.

For details ask for Lists 99 & 102.

LANCASTER & TONGE LTD.

ENGINEERS, IRON AND BRASSFOUNDERS

PENDLETON, MANCHESTER 6

TEL. PENDLETON 1484-5-6

GRAMS 'PISTONS' MANCHESTER

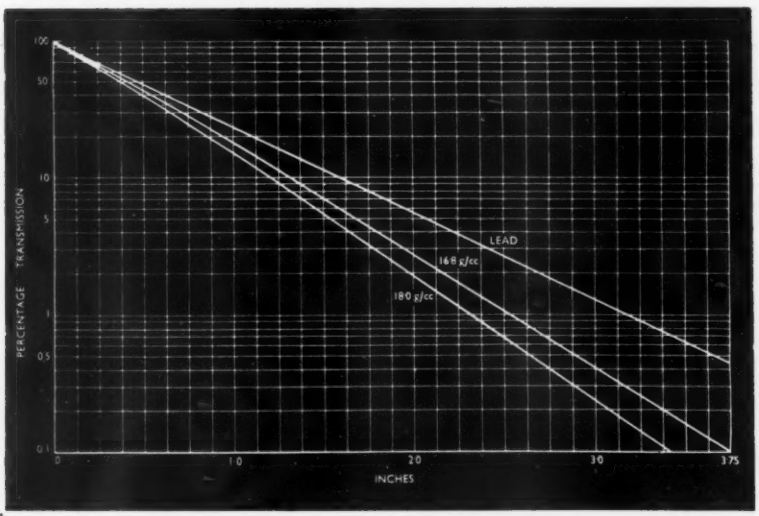
G.E.C.

HEAVY ALLOY

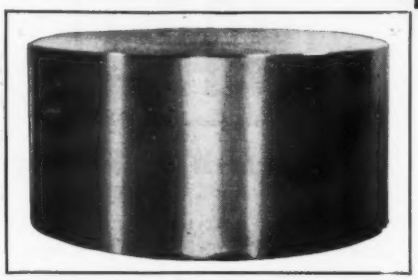
supplied in densities

16.8,17.0,17.5,18.0g/cc(nominal)

- ***for screening purposes***
- ***for balance weights***



Broad beam absorption of Gamma-radiation from COBALT-60. Density: 16·8 g/cc. and 18·0 g/cc.



The above piece of G.E.C. Heavy Alloy was made for the United Kingdom Atomic Energy Authority. It weighs 660 lb.

THE GENERAL ELECTRIC CO. LTD., Component Sales Dept., Osram Metals, East Lane, Wembley, Middlesex. Arnold 4321

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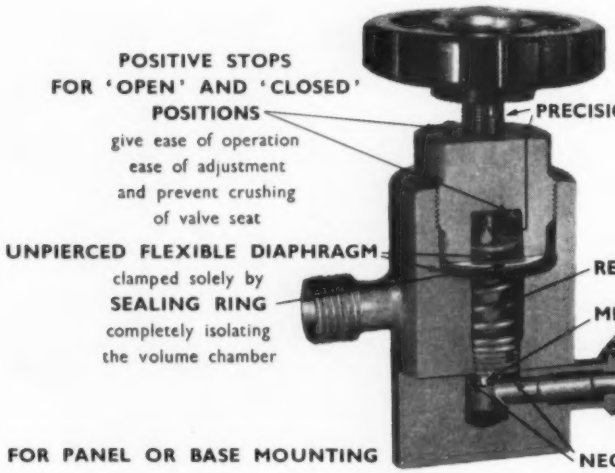
THE SENSITIVE CONTROL VALVE WHICH IS REALLY LEAK-FREE



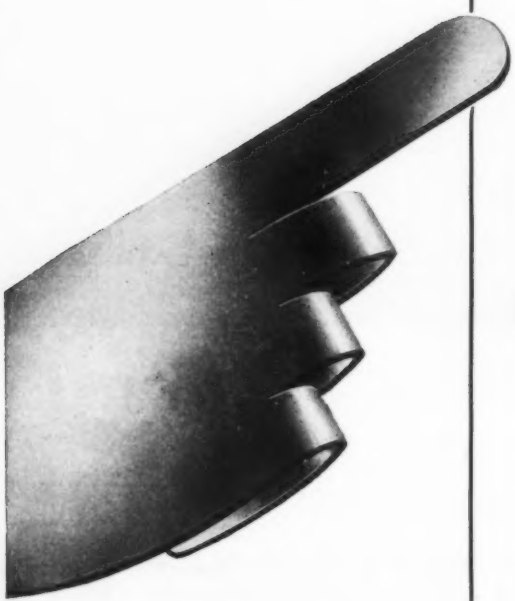
Designed, manufactured and patented by Rollason Aerocessories Limited, this sensitive control valve has widespread applications in many industries.

PRECISION SPINDLE — does not pass through diaphragm; is not attached to it; presses a thrust pad down on the diaphragm transmitting the movement to the top of the valve stem against the pressure of a return spring thereby positioning the cone

Size ¼" B.S.P.	Type 6100–100	Recommended max.	+ 200 p.s.i.
„ ¼" Plain	„ 6100–101	„ „	+ 200 „
„ ¼" B.S.P.	„ 6000–100	„ „	+ 150 „
„ ½" „	„ 6200–100	„ „	+ 100 „

ROLLASON AEROCESSORIES LIMITED
CROYDON AIRPORT, SURREY, ENGLAND

Telephone: CROydon 7238



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MARINE
WELDING &
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THE LARGEST EVENT OF ITS KIND IN THE WORLD

Olympia · London
April 20 - May 4
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For full details, please write to the organisers:
F. W. BRIDGES & SONS LTD.
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18/8
Titanium
(LOW COBALT)
Stainless Steel Wire

Stainless Steel Wire, to this specification, is already being supplied by us in ever increasing quantities to meet the specific requirements of Nuclear Engineers and Designers. We shall welcome your enquiries for this and all other types of Austenitic Stainless Steel Wire.

Stainless Steel Wire Company Limited

THE BARRACKS · LANGSETT RD
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The above illustration shows a selective range of pure molybdenum articles fabricated by machining or spinning. We shall be pleased to quote against customers' drawings.

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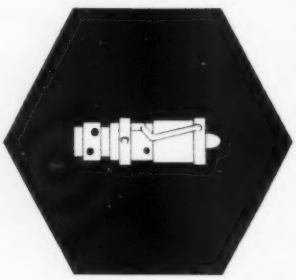

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廣告紙面の関係上製品の技術的細目は掲載しきれませんので詳しくは裏のカードの適当なナンバーに印をつけて原子力宛投函して下さればお答へします。

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14	37	60	83	106	129	152	175	198
15	38	61	84	107	130	153	176	199
16	39	62	85	108	131	154	177	200
17	40	63	86	109	132	155	178	201
18	41	64	87	110	133	156	179	202
19	42	65	88	111	134	157	180	203
20	43	66	89	112	135	158	181	204
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210	216	222	228	234	240	246	252	258
211	217	223	229	235	241	247	253	259
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7	30	53	76	99	122	145	168	191
8	31	54	77	100	123	146	169	192
9	32	55	78	101	124	147	170	193
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11	34	57	80	103	126	149	172	195
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13	36	59	82	105	128	151	174	197
14	37	60	83	106	129	152	175	198
15	38	61	84	107	130	153	176	199
16	39	62	85	108	131	154	177	200
17	40	63	86	109	132	155	178	201
18	41	64	87	110	133	156	179	202
19	42	65	88	111	134	157	180	203
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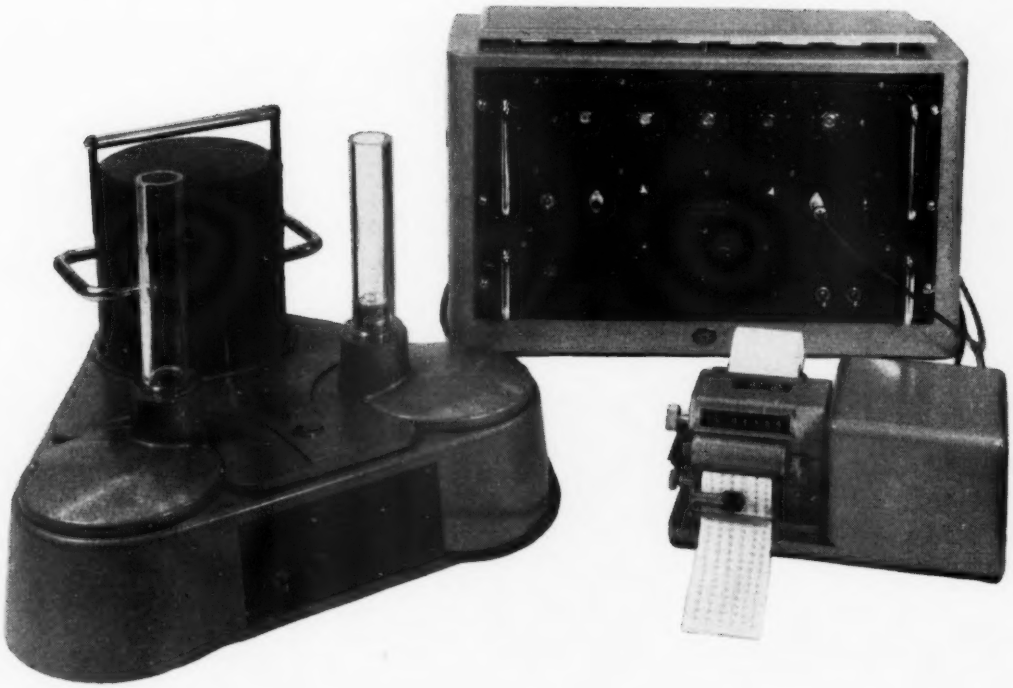

This new Sample Changer is designed for the automatic examination of a larger number of planchet supported samples. It may be used with almost any conventional scaling or timing equipment—the illustration shows a typical assembly of Labgear instruments for print-out of time-per-unit-counts.

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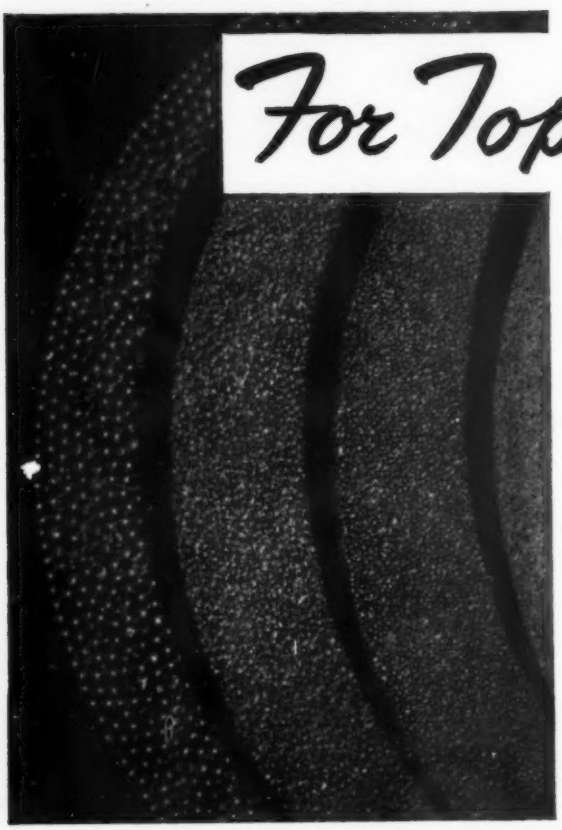

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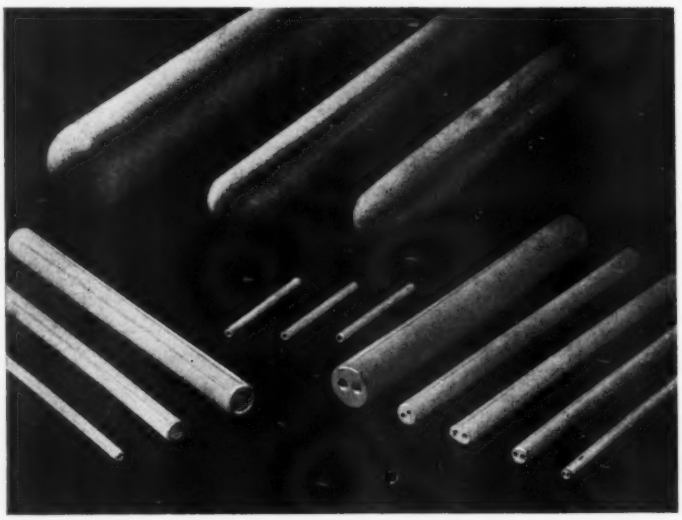

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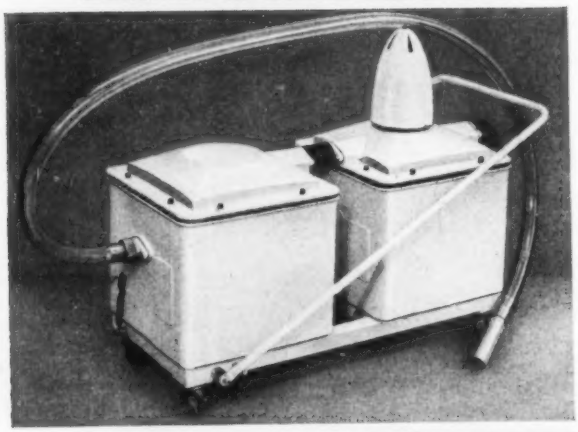
Specialists in cleaning of Nuclear Reactors and Power Plant



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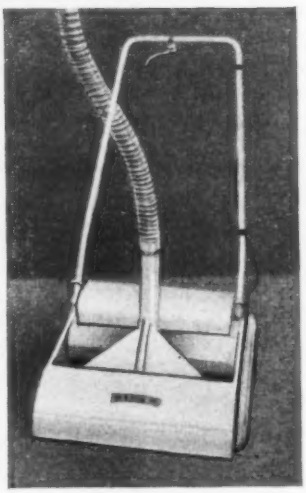
By action of the powerful suction unit, dust laden air, at 100 cu. ft. per minute, is drawn through the primary filter to extract all particles above 2 micron size, and into the Absolute cell with 100% filtration of particles down to 0.3 micron. Major contamination is retained in a polythene liner for easy and safe destruction.

"A floor scarifier for removal and collection of hazardous deposits. Adapted for use in conjunction with user's extractor plant." **CODE 92**



and manufacturers of specialised floor cleaning equipment for the Nuclear Power Industry

CIMEX LIMITED

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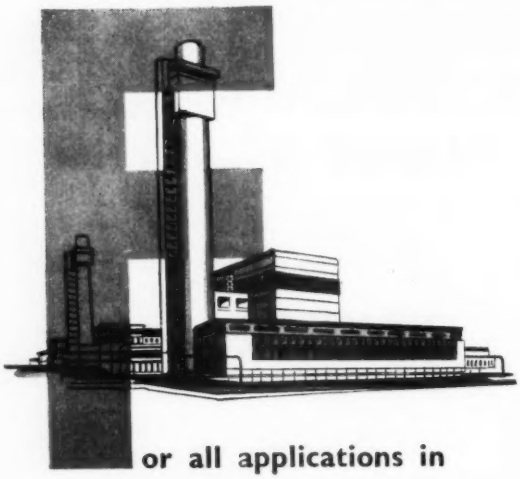

or all applications in Nuclear Power plants . . .

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bolts, nuts, screws and other fasteners with corrosion, contamination and heat resistant properties.

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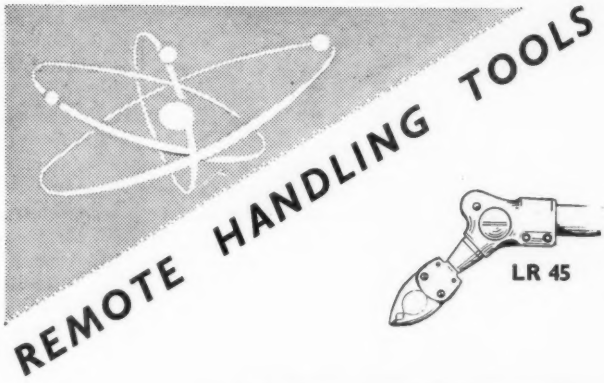

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This model has Jaw Rotation through 400° by remote control from the handle section, and is available up to 12 feet in length.

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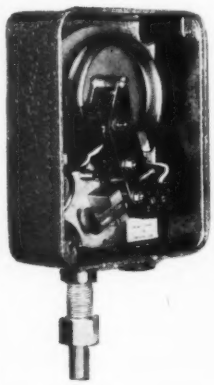

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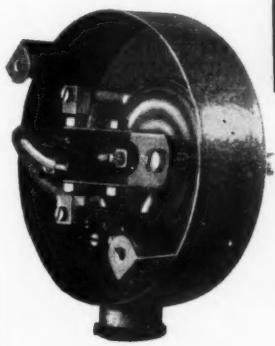
150 p.s.i. to 5000 p.s.i.

For use with liquids or gases, and may also be supplied with Stainless Steel elements for corrosives. Contact rating 5 amps at 250 volts A.C. Also available in weatherproof and flameproof housings.



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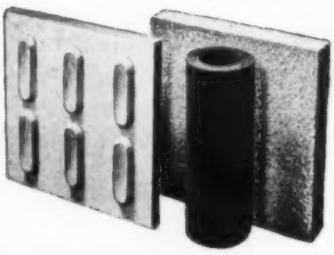

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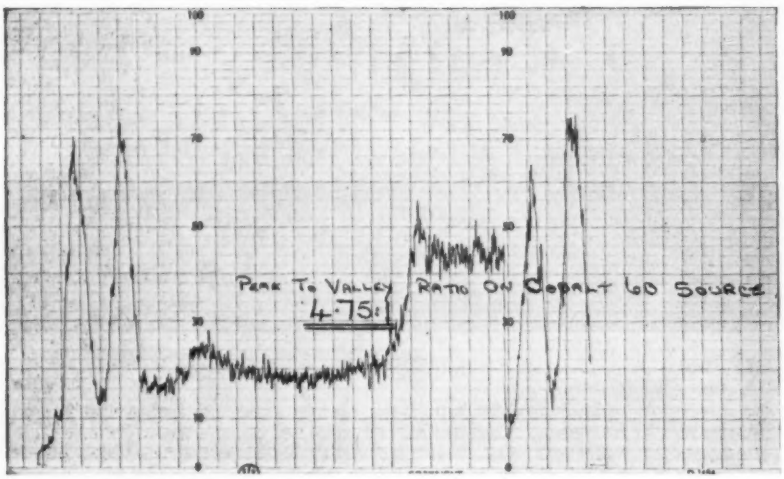

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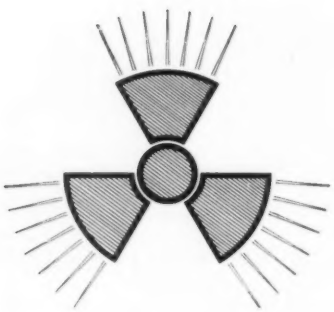

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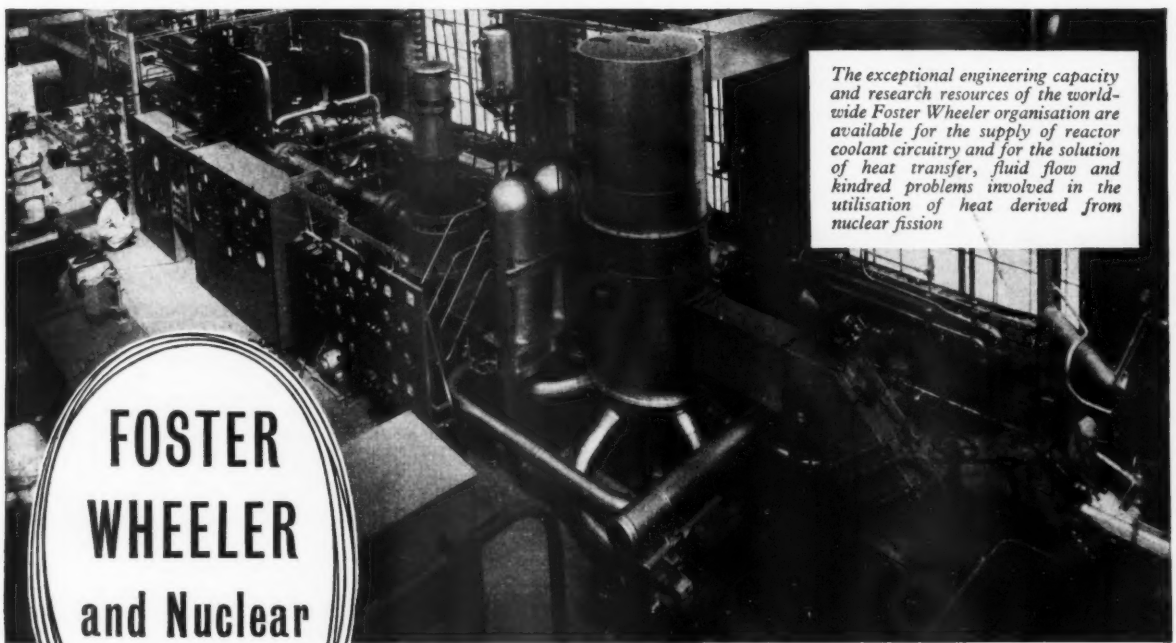

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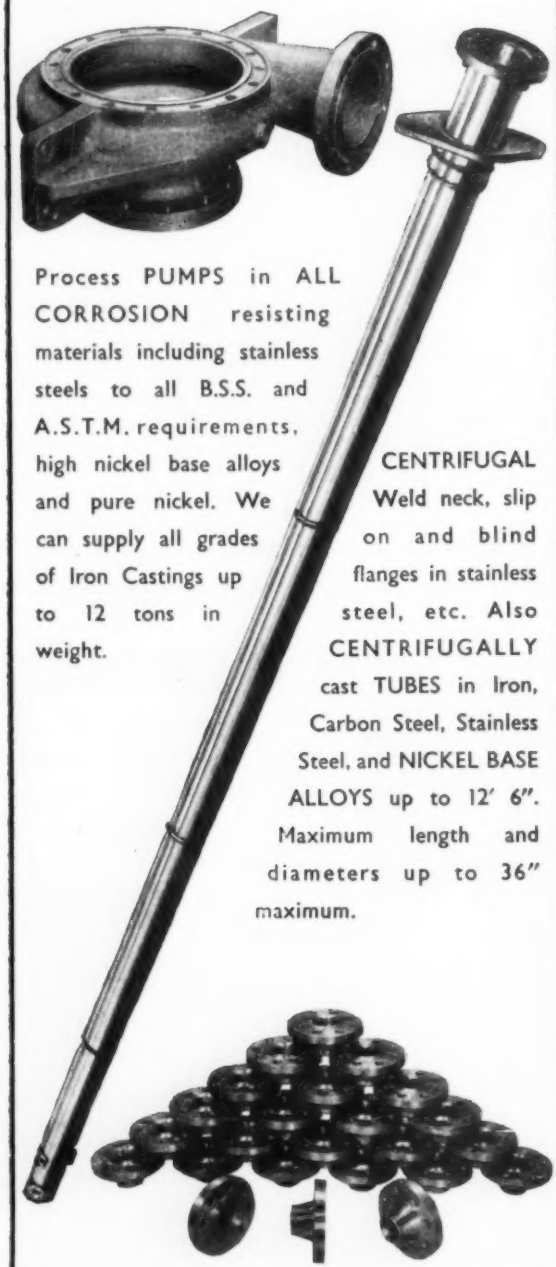

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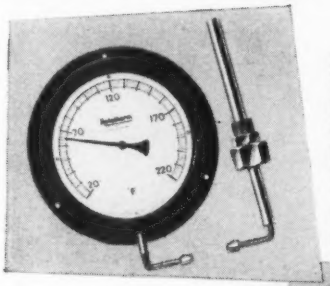

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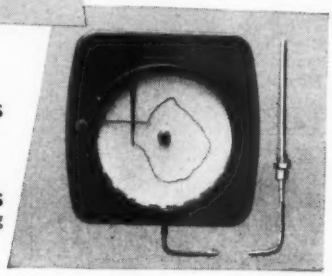

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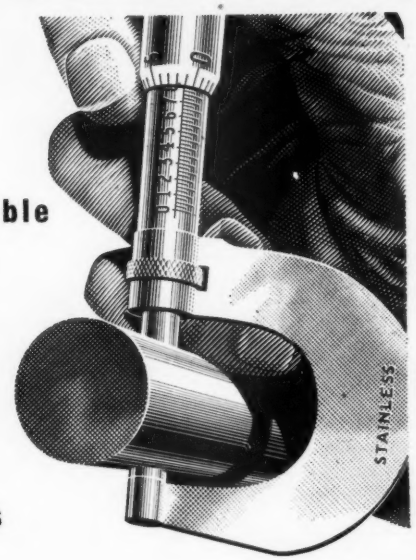

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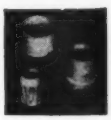

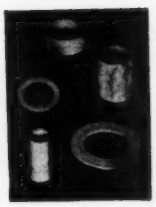

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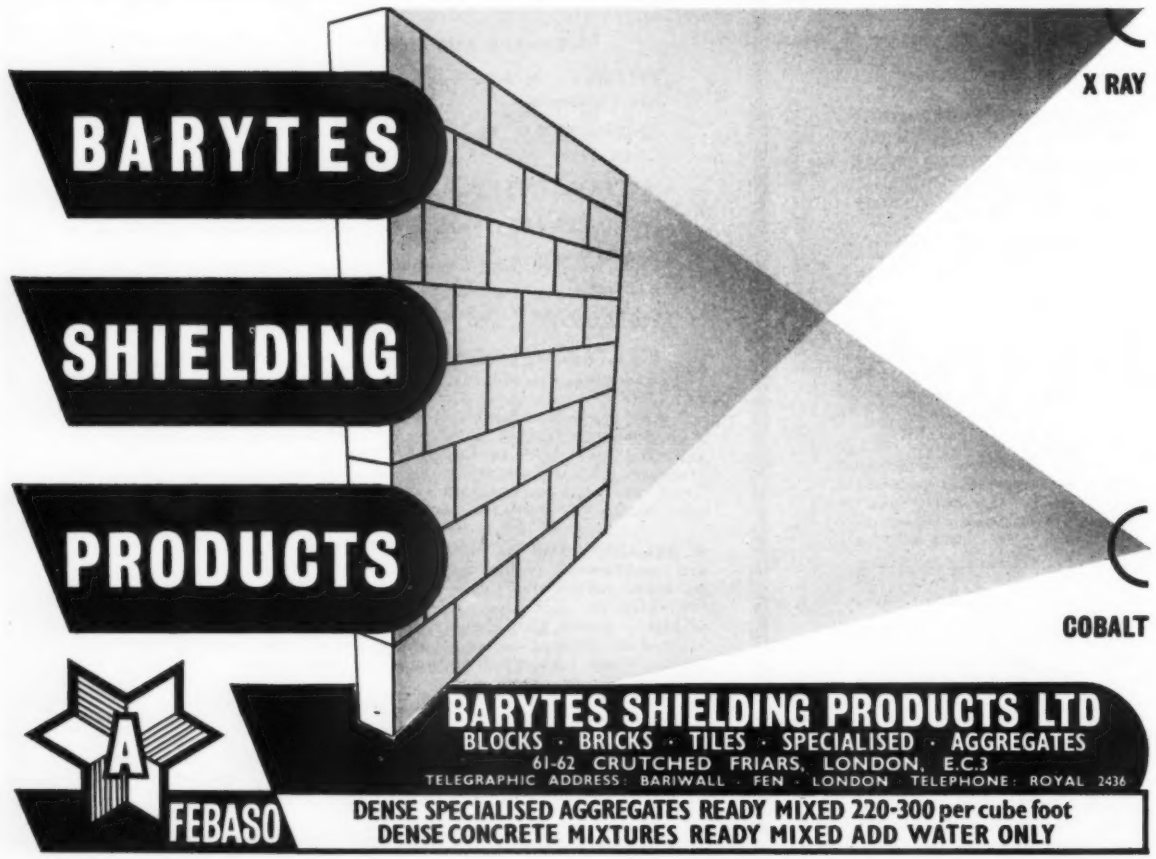
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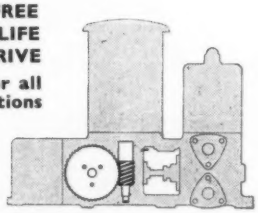

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